INSTRUCTION MANUAL

VisualWeather™ Software

Version 3.1

Revision: 4/11

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VisualWeather™ Software
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VisualWeather™ Software

1. Introduction

VisualWeather software is designed to work with Campbell Scientific's pre-configured weather station models ET106, ET107, Toro T107, and MetData1, or custom-configured weather stations. This software will allow you to:

- Create and send programs to one or more weather stations.
- Select a mode of communication (e.g., phone modem or RF) for each weather station.
- Define a data retrieval schedule for each station.
- Connect to any weather station that has been configured with VisualWeather.
- View a graphical display of a weather station's current weather conditions.
- Print a summary of each weather station's configuration.
- Monitor the "health" (e.g., battery voltage, internal temperature) of each weather station.
- View and print preformatted reports (tables and graphs) from the data retrieved from each weather station.
- Perform post-processing on retrieved data to produce special meteorological and agricultural reports (e.g., evapotranspiration, dewpoint).
- Set up a schedule to automatically print reports (Batch Reports).
- Export retrieved data to an ASCII file so it can be imported into a spreadsheet or other software package for further data processing.

These tasks can be accomplished by clicking a few buttons and following the on-screen instructions. It requires no computer experience or in-depth technical knowledge of the weather station equipment. We hope all users—novices or experts—will find VisualWeather a very easy to use, yet powerful, tool for managing a weather station network.

NOTE

This software is primarily designed to calculate quantities, such as evapotranspiration (ETo), crop water needs, and growing-degree-days, which are important to the agricultural community. This software expects that your weather station has at least a 'full set' of sensors, namely sensors that measure temperature, relative humidity, precipitation, solar radiation, and wind speed/wind direction. If your weather station does not measure these weather conditions, then you may not be able to utilize the full potential of this software. For example, if your station does not have a humidity sensor, then you will not be able to get reports on ETo or crop water needs.

It is best to consult a CSI applications engineer who will advise you on sensors required for your needs.

1.1 Background

Each weather station consists of a datalogger and a group of sensors. The sensors are designed to measure environmental factors such as air temperature or solar radiation. The datalogger measures the sensors and processes and stores the results. The stored results (final storage data) can be retrieved with a PC using communication software.

Dataloggers must be "told" (that is, programmed) when and how to measure the attached sensors, process these measurements, and store the information in final storage. Datalogger programming can be a formidable task for many users. However, when using VisualWeather with ET106, ET107, Toro T107, and MetData stations, you simply select the sensors connected to the weather station and the program is generated for you! For users with stations other than our preconfigured weather stations, VisualWeather supports custom weather station configurations. Short Cut for Windows is included in VisualWeather (Tools | Short Cut), so that programs can easily be created for any datalogger type. Once the program is generated and transferred to the datalogger, variables or input locations in the datalogger are associated with the measurement values required by the VisualWeather database for generation of reports.

1.2 What's New in VisualWeather 3.1

VisualWeather 3.1 includes the following enhancements from VisualWeather 2.3:

- Support for the ET107 and Toro T107
- Enhanced Station Data screens
- Improved web output support
- Improved FTP support
- Enhanced Station Status window
- Changes to the database for faster report generation
- Global Units option which controls output units for reports and Station Data screens
- The user now has the ability to set the units used for barometric pressure and wind speed
- VisualWeather can now display the user interface component text (for buttons, dialog boxes, etc.) in an alternate language, if a separate VisualWeather language package has been installed

2. Installation

2.1 Upgrades

2.1.1 For Users Upgrading from VisualWeather 2

If you have VisualWeather 2 installed on your computer, when you run the installation the existing version will be updated with the new files. VisualWeather will continue to use the existing stations, databases, reports, etc.

2.1.2 For Users Upgrading from VisualWeather 1

VisualWeather 3.X will not upgrade an existing VisualWeather 1 installation. Significant changes were made to the database structure for VisualWeather 2. Existing VisualWeather databases and reports are not compatible with, nor will they import into, the new software. If VisualWeather 1 is detected on your computer system during installation of VisualWeather 3.X, you will be required to install the program executable and supporting files in a different directory, as well as choose a different working directory.

The default installation directory for VisualWeather 3.X is C:\Program Files\Campbellsci\VisualWeather. The default working directory for VisualWeather 3.X (the directory in which all the data and report files are stored) is C:\Campbellsci\VisualWeather. (Note the lack of a space in the VisualWeather name; previous installations used the name Visual Weather.) Subfolders are created in the working directory for the database (DataBase), exported ASCII files (Export), custom images that are associated with stations (Images), program files that are generated for preconfigured weather stations during setup (ProgFiles), reports that are generated when using VisualWeather (Reports), the RTMC projects used for Station Data (RTMC), and web output (Web). A Sys directory also contains setup information and log files for your copy of VisualWeather.

While VisualWeather 1 did not include the Short Cut program generator, it is included in other Campbell Scientific software packages and also offered as a stand-alone download from our web site. Therefore, you may already have a copy on your computer. VisualWeather will update the existing version of Short Cut. Any files created using previous versions of Short Cut for Windows will be compatible with this current version. Additionally, if this version of VisualWeather is uninstalled, the Short Cut program generator will remain installed on the computer if it was installed prior to the installation of VisualWeather.

2.2 Hardware and Software Requirements

The recommended minimum hardware for VisualWeather is a computer running Windows XP, Vista, or 7.

NOTE If you need to contact weather station(s) in remote locations, then you may also need RF modems and radios or an analog phone line and a phone modem. VisualWeather can detect modems installed on your computer provided they were configured in your computer's Window environment. During configuration of a new weather station you will find it convenient to select the detected modem.

NOTE Some newer computers have USB ports instead of serial ports for communication with other devices. Communication using VisualWeather requires serial communication. If your computer has only a USB port, you will need a USB to serial port adapter.

To install the software, insert the VisualWeather CD into the CD ROM drive of your computer. The installation process should begin automatically. If it does not begin, access your CD ROM drive and double-click the SETUP.EXE file. Follow the on-screen instructions to complete the installation.

2.3 Configuration of TCP/IP and Telephony Services

TCP/IP and Telephony services must be installed and enabled on the computer for VisualWeather to run. To determine if both of these services are installed and enabled, access the Windows Control Panel (Start | Control Panel). From the Control Panel, open Administrative Tools and choose Services. The list of installed services is typically displayed in alphabetical order. Review the list for entries titled TCP/IP and Telephony.

The Startup Type for each service should be listed as "Automatic" or "Manual". If either of the services is installed but listed as "Disabled", right click the service to bring up a floating menu. Select Properties, and on the General tab, change the Startup Type to Automatic or Manual. If a service is not installed refer to the Windows operating system help for installation information. In Windows XP, the Help & Support Center can be opened by selecting the My Computer icon on the desktop and pressing F1. Typing in **TCP/IP Service** in the Search field will display a link to "Install Simple TCP/IP Services". Typing in **Telephony Service** will display a link to "Add a Telephony Service Provider".

NOTE You may need to contact your IT department for complete information for configuring these services.

3. Starting Out

3.1 Before You Begin

Before configuring a weather station in VisualWeather, the following tasks must be completed:

- Install VisualWeather on your computer.
- Install a weather station with the desired sensors connected properly to the station. (Please refer to the Weather Station manual.)
- Charge the battery supplying power to the station (12 Volts DC).
- Ensure communication hardware (e.g. modem, phone line, radio, etc.) is connected properly and functioning.

3.2 Running VisualWeather

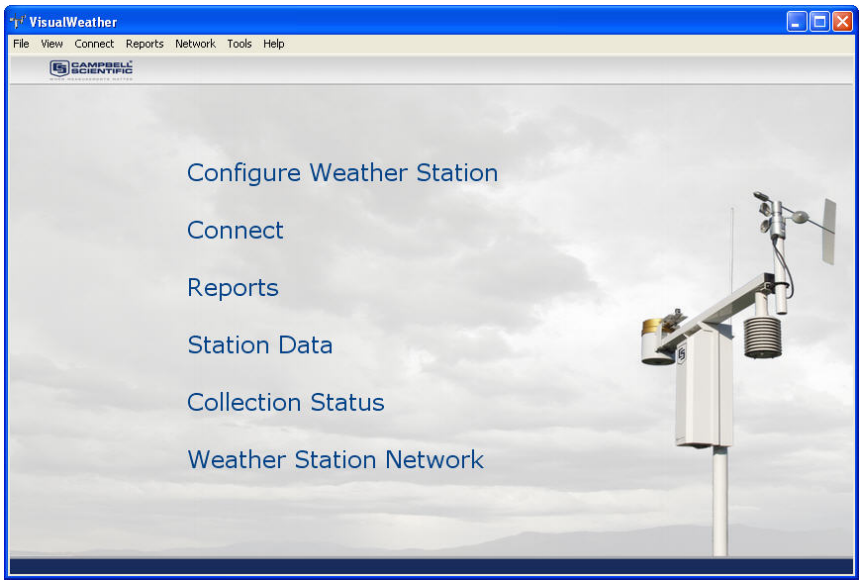
To run the VisualWeather Software, click the desktop icon (if it was added to the desktop during the install) or select Programs | Campbell Scientific | VisualWeather | VisualWeather from the Windows Start menu.

3.3 Getting Help

VisualWeather has a complete on-line help system. Most screens have a Help button that, when pressed, will bring up help about the screen. In addition, help for any screen can be displayed by pressing the F1 key on your computer. A Help file Table of Contents, an Index, and a Search function can be displayed by selecting VisualWeather Help from VisualWeather's main menu.

4. The Home Screen

The VisualWeather Home screen is the starting point for all tasks in the software:



The most common tasks (configuring a weather station, connecting, creating reports, displaying station data, monitoring data collection status, and viewing the network) are shown as headings on this screen. Less common tasks (batch reports, importing data, exporting data) are accessible from VisualWeather's menu.

5. Configure Weather Station

5.1 Configuring a New Weather Station in VisualWeather

Configuring your weather station in VisualWeather is simple using the EZSetup Wizard. To begin configuring a weather station select **Configure Weather Station** or Network | Configure Weather Station from the main menu of the Home screen.

The EZSetup Wizard will walk you through each step in the setup process. If help is needed on a specific screen, press the **Help** button at the bottom right of the window. To move forward and backward in the EZSetup wizard use the **Previous** and **Next** buttons. At any time you can click the **Cancel** button. This will cancel configuring the weather station.

After you have progressed through all steps of the wizard, press the **Finish** button to save the configuration and return to the main VisualWeather window.

5.2 After Configuring a Weather Station

After setting up your weather station, VisualWeather will automatically collect data at the intervals specified (if scheduled collection is enabled). If batch reports have been created (see Batch Reports section 7.3), VisualWeather will automatically create reports using the collected data.

Note, however, that VisualWeather must be running for automatic scheduled data retrieval and batch reports to be performed. If for some reason you must close VisualWeather, these tasks will resume once the software is restarted. Data will not be lost unless the software has been closed a sufficient amount of time for the weather station to begin overwriting its oldest data with new data. This can be anywhere from 10 to 30 days depending upon the station type selected. It is prudent to retrieve data at least daily to protect against loss of data.

Data collection from the stations can be verified by viewing the collection schedule. See the collection schedule by selecting **Collection Status** from the home screen or choosing Network | Collection Status from the VisualWeather menu (see Monitoring the Data Collection Status section 9).

5.3 Editing an Existing Weather Station Configuration

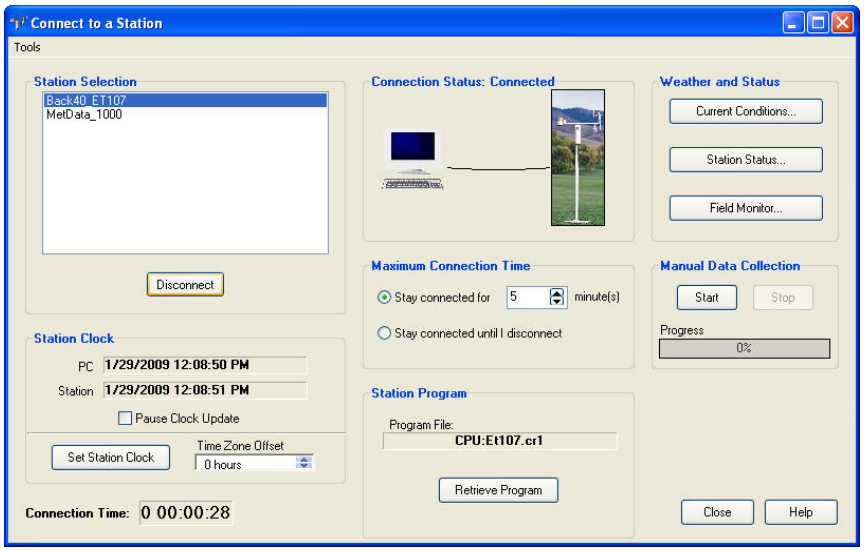
Weather stations that have been set up in VisualWeather can be edited by selecting Network | Edit Weather Station from the VisualWeather menu and selecting a station from the resulting dialog box. This will open the EZSetup Wizard for the station. To navigate to a specific section of the setup, select the section from the Progress panel on the left side of the Wizard.

6. Connect

6.1 Manually Connecting to a Weather Station

In addition to performing automatic scheduled data retrieval, you can connect to a weather station manually and perform system maintenance, monitor current weather parameters, or retrieve data.

To connect to a weather station, select the **Connect** heading or Connect | Connect from the main menu of the Home screen. The Connect to a Station screen will be shown.



All weather stations that have been configured using VisualWeather will be listed on the left side of the screen under the Station Selection field. Select the weather station you wish to communicate with and click the **Connect** button. VisualWeather will attempt to communicate with the weather station. Once connected, the Connection Status will display Connected and other buttons on the window will be enabled.

The amount of time that your computer has been connected to the weather station is indicated by the **Connection Time** field at the bottom left part of the screen. When communication is initiated manually, it will be maintained until you reach the Maximum Connection Time (see below), you click the **Disconnect** button, you return to the Home screen, or you close VisualWeather. Note that whenever you are connected to a weather station, the weather station uses more power, phone connections remains active (thus, phone costs may be incurred), no other station on that COM port can be contacted for data, and no other users can connect to the weather station.

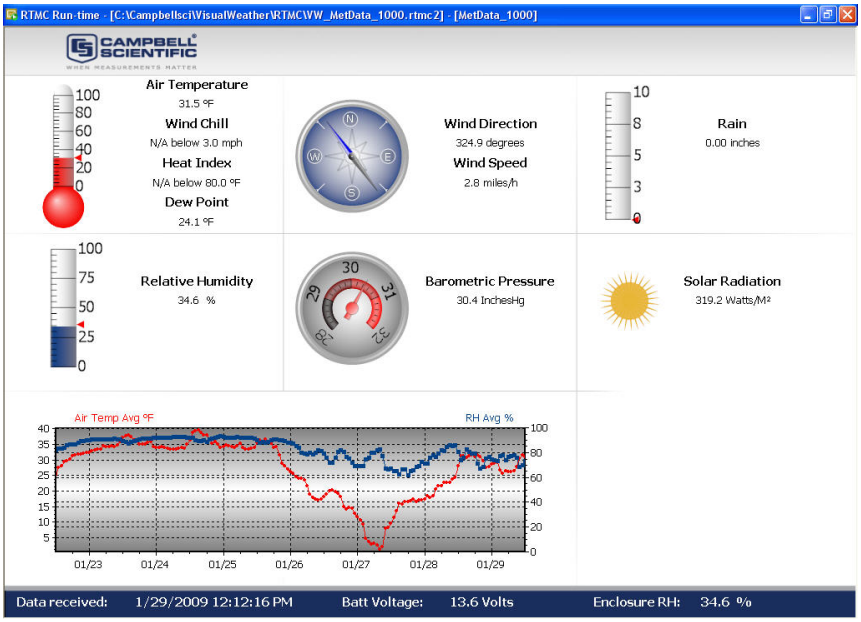
6.1.1 Maximum Connection Time

Because phone modem connections can be costly and communication with a weather station can put a heavy load on the station's power supply, by default, any manual connection to the station will be terminated automatically after five minutes.

The **Maximum Connection Time** group box allows you to change the amount of time after which VisualWeather will terminate communication, or to override this feature completely. Select the **Stay connected for X minutes** option if you wish to have the connection disconnected automatically after a specified amount of time. If you wish to be connected until you manually disconnect, select the **Stay connected until I disconnect** option. Communication with the weather station will be maintained until you click the **Disconnect** button.

6.2 Monitoring Current Conditions

Current weather conditions can be viewed after connecting to a weather station. Click the **Current Conditions** button to show the Current Conditions Screen.

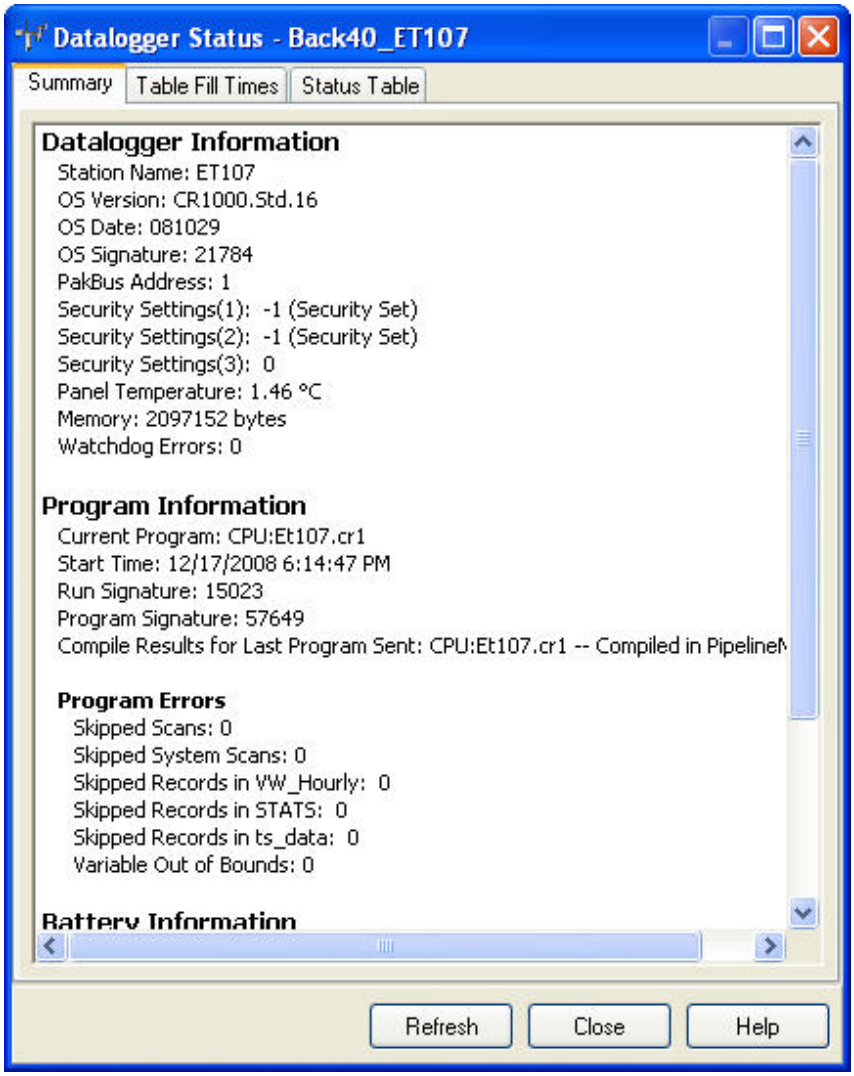


The data displayed will be based upon the sensors that were selected when the weather station was configured. Custom stations will show only those values that were set up in the Data Files/Mapping section when configuring the weather station (see Section 11.2 Real Time Field Mapping). The units used will be based on the options chosen from VisualWeather's Tools | Options menu item.

The data that is displayed is the same as that displayed by Station Data. (See Section 8 Station Data for more information.) However, when monitoring current conditions through the connect window, data will only be displayed for the station to which you are connected. Also, VisualWeather will actively collect data on a one-second interval to be displayed when monitoring current conditions. (Data displayed by Station Data must be collected manually or on a schedule.)

6.3 Monitoring Station Status

When you have a connection established with a weather station, you can view the station's status. This can be done by clicking the **Station Status** button.



The Station Status window has three tabs. The **Summary** tab provides an overview of important status information in the datalogger, including the information about the datalogger model and its firmware, program details, battery voltage levels, and card memory (if one is present). Right click within this window to display a menu for printing the summary or saving this information in a file.

NOTE Only the Summary tab is available for array-based dataloggers.

The **Table Fill Times** tab lists the tables in the datalogger, along with the maximum number of records the table can hold, the estimated amount of time that it will take the table to fill, and the estimated date and time that the table will fill based on the time the datalogger program was downloaded and the

table size. A data table can be reset from this window by pressing the **Reset Tables** button.

NOTES

No Table Fill Time statistics will be shown for a CR200 Series datalogger, because they cannot be calculated for this datalogger model.

For the CR10XTD, CR10XPB, CR510TD, CR510PB, CR23XTD, and CR23XPB, the Time of Fill will not be shown and you will not have the option to Reset Tables.

Resetting a table will erase the data in the datalogger and in the data cache.

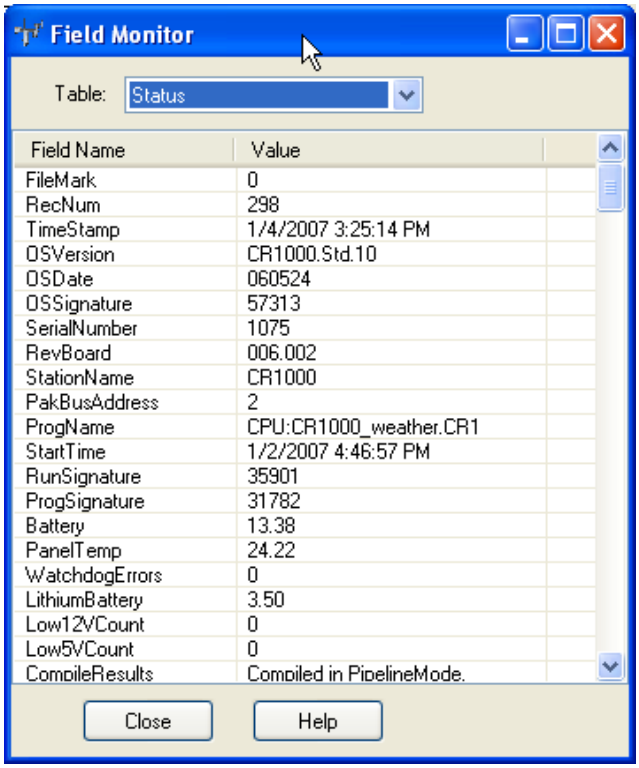
The **Status Table** tab lists all of the status table fields in the datalogger along with their values. By default, all of the fields in the status table are displayed. To select only certain status data to be viewed, press the **Select Fields** button. This will display a list of the status data available in the datalogger. Select one or more of the fields and then press **OK**. The current values will be displayed in the table. If you select a cell within the status table and right click, a short cut menu will be displayed. From this menu you can view/edit a value (if it is a writable value).

Press **Refresh** to prompt VisualWeather to query the datalogger and update the values again. This refresh option is also available from the right click menu.

Refer to individual datalogger manuals for a list of fields included in the status table for each datalogger and a description of each.

6.4 Field Monitor

Clicking the **Field Monitor** button will bring up a screen that allows you to view the numeric values for a table.



Select the table you want to view from the **Table** list box; the values for that table are displayed in the cells. Right-clicking on a value and then selecting View/Edit will display the value in a separate dialog box and allow you to change the value (if it is editable).

NOTE For array-based dataloggers, there may be long delays before the values in the Field Monitor are updated when data collection is occurring. No updates can be done until data collection is completed.

6.5 Manually Collecting Data

To manually collect data from a weather station, click the **Start** button in the section of the screen titled **Manual Data Collection**. You will see the progress bar fill as VisualWeather is retrieving data. You can stop data retrieval at any time by clicking the **Stop** button.

6.6 Setting a Weather Station Clock

The station's clock and the PC clock times are shown on the Connect screen. When you click the **Set Station Clock** button, the station's clock will be set to the PC clock with the entered **Time Zone Offset**.

NOTE It is nearly impossible to synchronize the two clocks exactly, since it takes time to transfer the clock setting to the weather station.

6.7 Sending/Retrieving Programs to a Weather Station

The name of the program currently running in the weather station is displayed in the Station Program Group box.

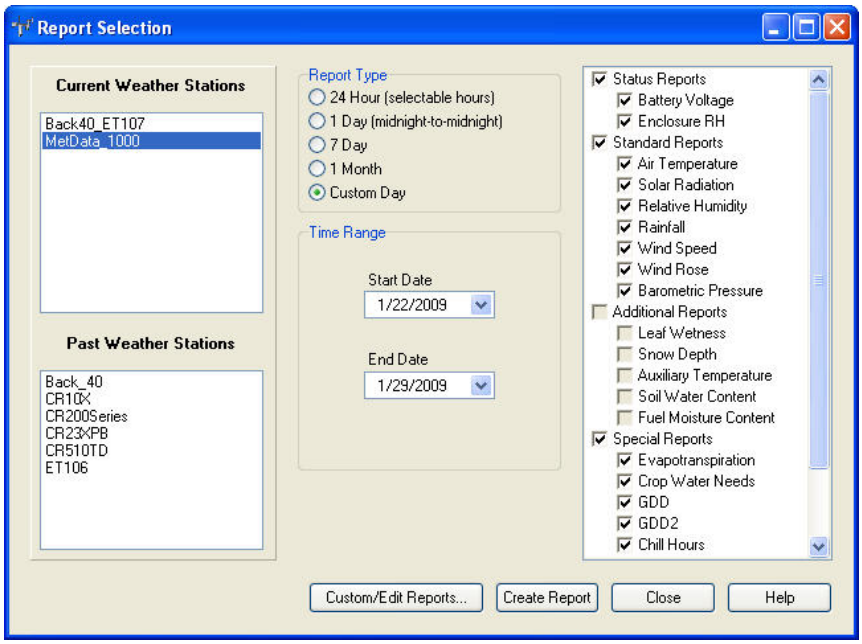
For debugging purposes it may be necessary to retrieve the program from the weather station. Click the **Retrieve** button and choose the location to save the file. The program will be retrieved from the weather station.

To send a new program to a datalogger, edit the configuration for a weather station by selecting Network | Edit Weather Station from the main VisualWeather menu (select the appropriate station from the resulting dialog box). Click **Send Program** from the EZSetup Wizard's Progress panel to navigate quickly to the Send Program page.

7. Reports

7.1 Manually Generated Reports

To generate reports, select the **Reports** heading or the Reports | Generate Reports menu item from the Home screen. The Report Selection Screen will be shown to allow you to select the type of report, time range of data to use, and reports to generate.



Select a current or past weather station. Current weather stations are those currently part of the network. Past weather stations are those that have been deleted from the network.

After a station is selected, use the option buttons to select the time range that the report should cover. Note that VisualWeather will not let you enter a time range for data that is outside of what is currently available in the database. The following report options are available:

24 hour Creates a 24 hour report, with a user-specified start date and time. As the start parameters are entered, the end date and time change accordingly to reflect a 24 hour period.

1 day Creates a 24 hour report for a specific date, which begins and ends at midnight.

7 day Creates a 7 day report, which begins on midnight of the start date and ends at midnight on the end date. As the start date is entered, the end date changes accordingly to reflect the 7 day period.

1 month Creates a report for a specified month, which begins on midnight of the first day of the month and ends at midnight on the last day of the month.

Custom Creates a report that starts at midnight of the specified start date, and ends at midnight of the specified end date.

Last, select the reports you wish to generate. Any reports that cannot be generated for the specific weather station type are disabled. The reports that are available for a custom weather station are based on the report parameters that were mapped to data fields during the configuration of the weather station (see 11.1 Report Field Mapping). Some reports require additional parameters that need to be set (see 7.2 Report Parameters). These parameters can be set and changed at any time by clicking the **Custom/Edit Reports** button.

The units used in the reports will be based on the options chosen from VisualWeather's Tools | Options menu item.

Formulas used for generating special reports are documented in the appendices.

7.2 Report Parameters

Some reports require parameters to be entered by the user. Reports needing additional information are the Wind Rose, Evapotranspiration, Crop Water Need, GDD, GDD2, and Chill Hours. The parameters can be initially set and then changed at any time by selecting a station on the Report Selection screen and then clicking the **Custom/Edit Reports** button.

Each tab on the screen allows you to change settings for the specified report. Enter the settings for the reports and click **OK** to save the settings. You can cancel changes at any time by clicking the **Cancel** button.

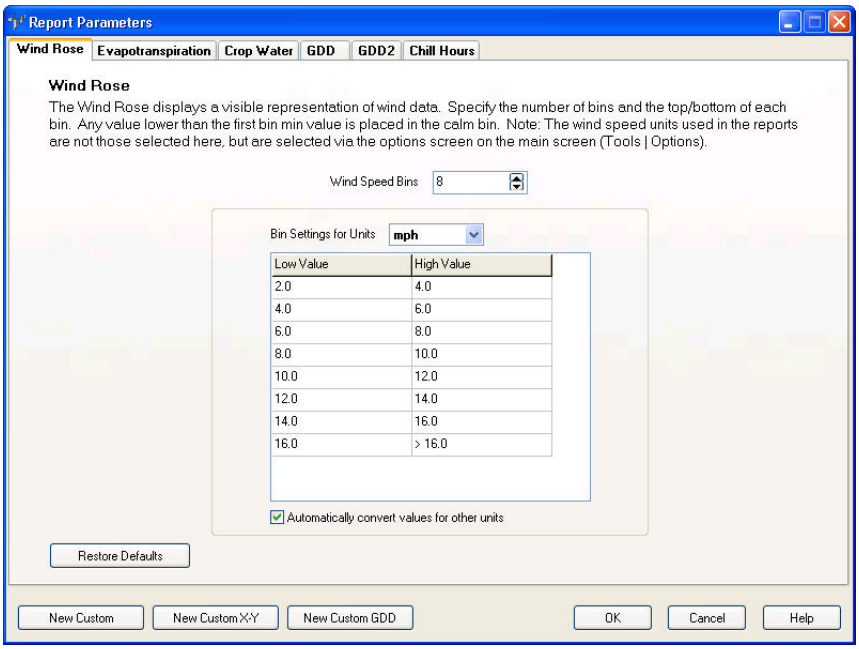
7.2.1 Wind Rose

WIND ROSE — Select the number of **Wind Speed Bins**. Specify the units (m/s, mph, km/h, or knots) for which you are entering values in the **Bin Settings for Units** field, and then enter the Low and High wind speed values

desired for each bin. Any wind speeds that fall in between the low and high will be placed in the corresponding bin. Any value below the low value of the first bin will be placed in the calm bin. The default values give the lows and highs that follow the Beaufort wind scale boundaries. If you have edited the wind rose parameters, at any time you can restore the defaults for the bins by clicking the **Restore Defaults** button.

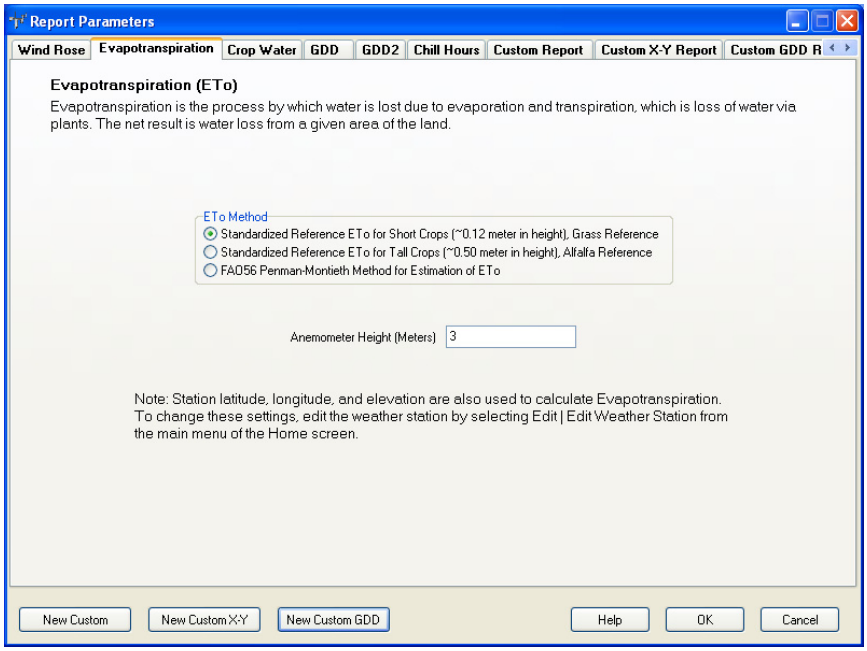
If **Automatically convert values for other units** is checked, the values entered will be converted and used for the other wind speed units automatically.

NOTE The wind speed units used in reports are not those selected here. The units used in reports will be those selected under Tools | Options on the main screen.



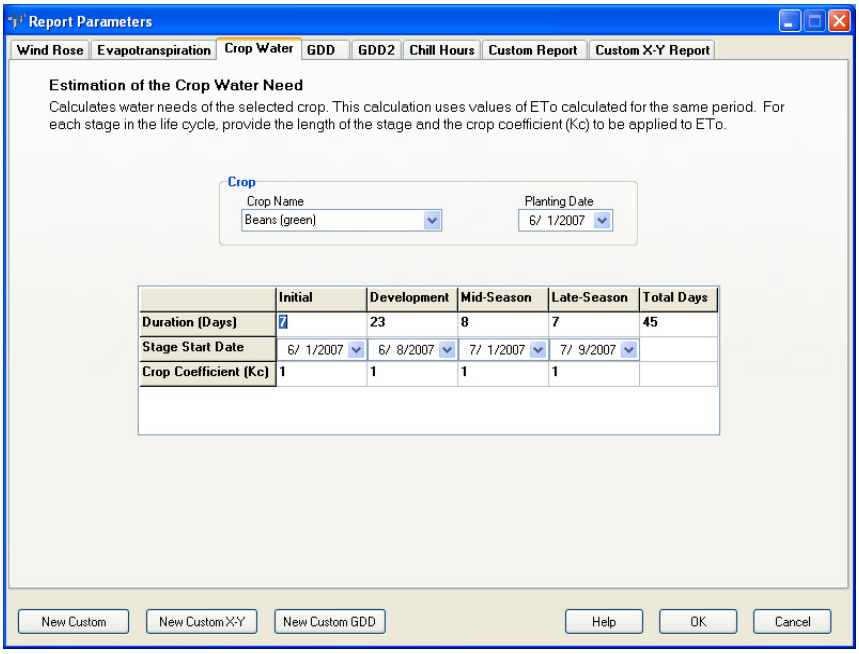
7.2.2 Evapotranspiration (ETo)

EVAPOTRANSPIRATION (ETO) — Select the ETo Method to be used and enter the anemometer height in meters. The latitude, longitude, and elevation are also used to calculate Evapotranspiration. These can be entered/changed in the EZSetup wizard by selecting Network | Edit Weather Station from the main menu of the Home Screen.


Report Parameters
Wind Rose
Evapotranspiration
Crop Water
GDD
GDD2
Chill Hours
Custom Report
Custom X-Y Report
Custom GDD R
Evapotranspiration (ETo)
Evapotranspiration is the process by which water is lost due to evaporation and transpiration, which is loss of water via plants. The net result is water loss from a given area of the land.
ETo Method
Standardized Reference ETo for Short Crops (~0.12 meter in height), Grass Reference
Standardized Reference ETo for Tall Crops (~0.50 meter in height), Alfalfa Reference
FAO56 Penman-Montieth Method for Estimation of ETo
Anemometer Height (Meters)
3
Note: Station latitude, longitude, and elevation are also used to calculate Evapotranspiration. To change these settings, edit the weather station by selecting Edit | Edit Weather Station from the main menu of the Home screen.
New Custom
New Custom X-Y
New Custom GDD
Help
OK
Cancel

7.2.3 Crop Water Need

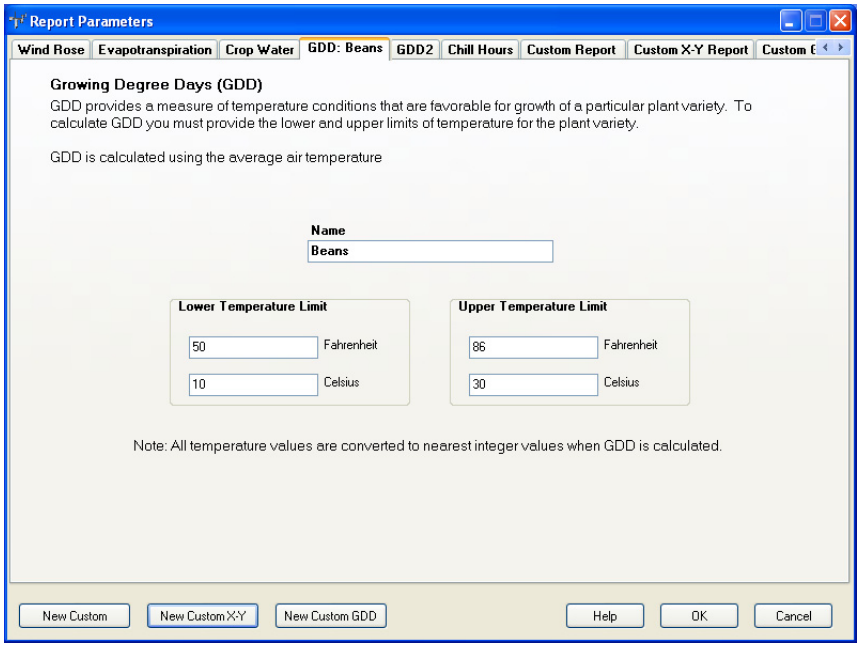
CROP WATER NEED — Select the **Crop Name** and enter the **Planting Date**. Next enter the **Duration (Days)** for each crop stage (initial, development, mid-season, late-season). The beginning date of each stage will be automatically calculated. Next enter the **Crop Coefficient** for each stage.



NOTE Alternatively, you can enter the stage start dates instead of the duration. The duration of each crop stage will be automatically calculated.

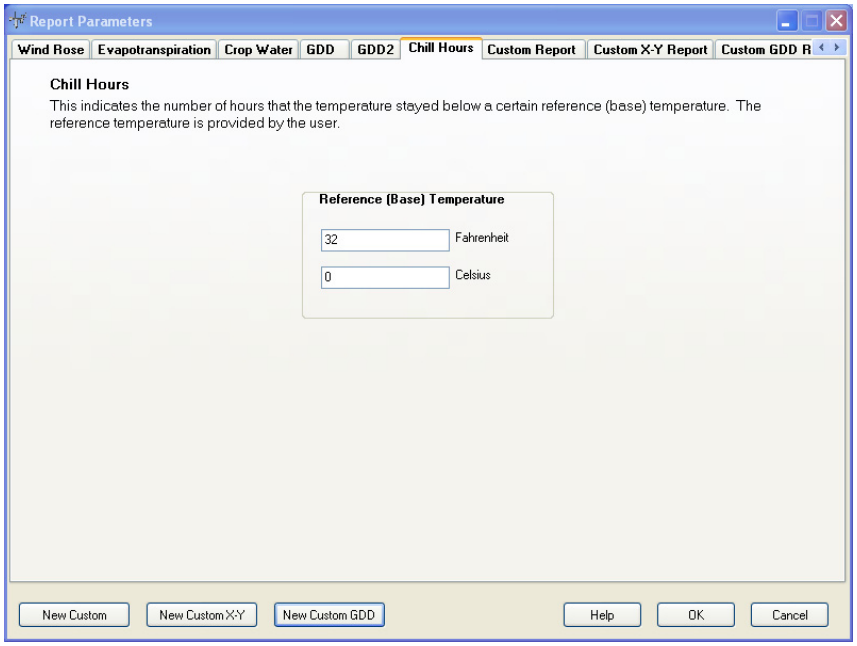
7.2.4 Growing Degree Days and Growing Degree Days 2

GROWING DEGREE DAYS AND GROWING DEGREE DAYS 2 — Enter the **Crop Name**. Next enter the **Lower** and **Upper Temperature Limit** for the crop. If Fahrenheit is entered, the Celsius value will be calculated automatically. If Celsius is entered, the Fahrenheit value is calculated automatically.



7.2.5 Chill Hours

CHILL HOURS — Enter the Reference (Base) Temperature in either Fahrenheit or Celsius. The other field value will be calculated automatically.



7.2.6 Custom Reports

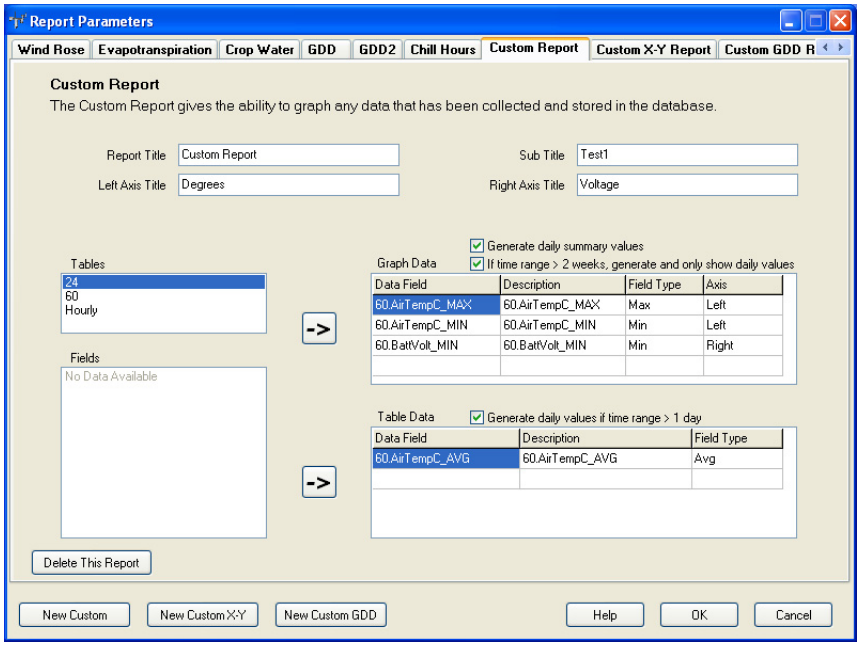
Custom reports are available that let you plot one or more traces on a graph and/or monitor one or more data values in a table. To create a custom report, press the **New Custom** button on the **Custom/Edit Reports** screen.

The **Report Title** and **Sub Title** fields are used to provide headings for the graph. The **Left** and **Right Axis Description** fields are used to provide a label for each axis.

The tables that are being collected to the database are listed in the **Tables** field. When a table is selected from this list, the data values in that table appear in the **Fields** list.

Highlight a data value from the list and click the top right-pointing arrow (or double-click the value) to add it to the list of values to be graphed. The type of output for the data value can be specified by clicking the cell within the **Field Type** column to display a list box of output types (Max, Min, Avg, Sample, or Other). To specify whether the value is plotted on the right or left axis of the graph, click within the **Axis** cell and select Right or Left from the list box that is displayed. A data value can be deleted from the list of values to be graphed by right-clicking and choosing Delete. Selecting **Generate daily summary values** will cause daily summary values to be shown on the graph. For example, if a maximum air temperature is being graphed, the daily maximum air temperature will be indicated on the graph. Selecting **If time range > 2 weeks, generate and only show daily values** will cause only daily values to be graphed if the time range for the report is greater than two weeks.

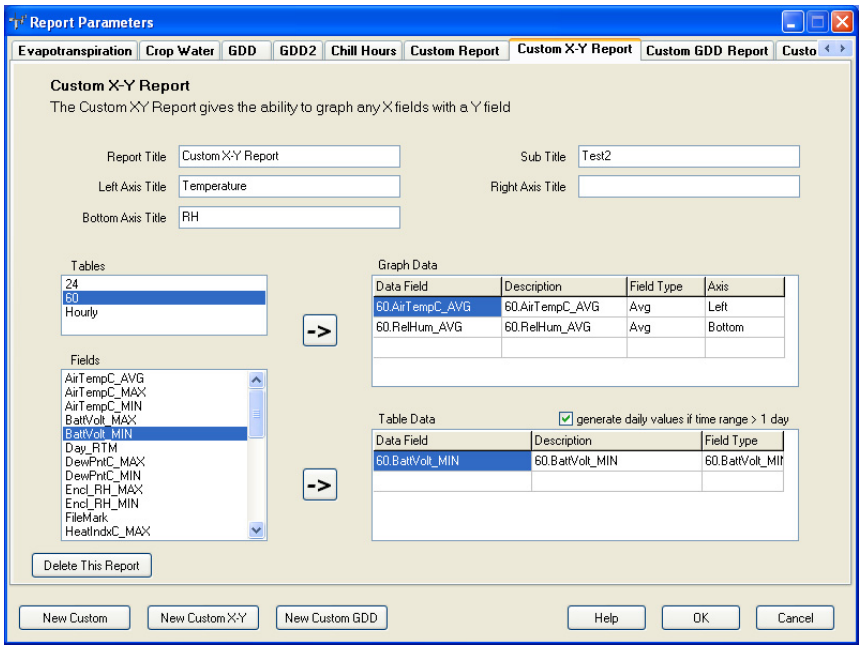
Highlight a data value from the list and click the bottom right-pointing arrow to add it to the list of values to be monitored in the table. Selecting **Generate daily values if time range >1 day** will cause only daily values to be monitored if the time range for the report is greater than one day.



7.2.7 Custom X-Y Reports

Custom X-Y report are available that allow you to plot one or more X-Y traces on a graph and/or monitor one or more data values in a table.

The user specifies what will be used for both the X axis data values and the Y axis data values on the graph. Each Y axis data value is plotted against the X axis data value with an identical timestamp.



The **Report Title** and **Sub Title** fields are used to provide headings for the graph. The **Left, Right** and **Bottom Axis Title** fields are used to provide a label for each axis.

The tables that are being collected to the database are listed in the **Tables** field. When a table is selected from this list, the data values in that table appear in the **Fields** list.

Highlight a data value from the list and click the top right-pointing arrow (or double-click the value) to add it to the list of values to be graphed. The type of output for the data value can be specified by clicking the cell within the **Field Type** column to display a list box of output types (Max, Min, Avg, Sample, or Other). To specify whether the value is plotted on the right, left or bottom axis of the graph, click within the **Axis** cell and select Right, Left or Bottom from the list box that is displayed. There must be one and only one data value selected for the bottom axis. Multiple data values can be selected for both the right and left axes. A data field can be deleted from the list of values to be graphed by right-clicking and choosing Delete.

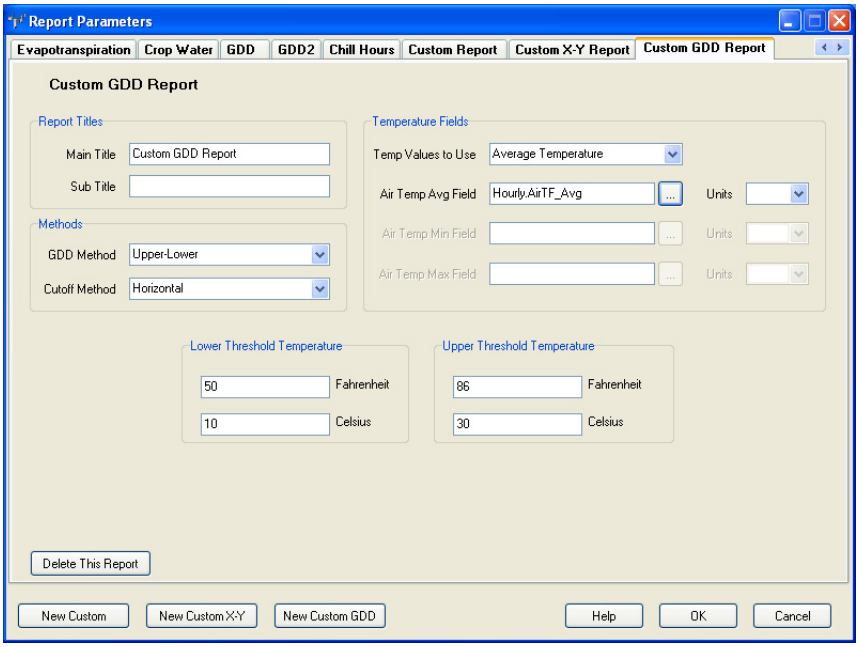
Highlight a data value from the list and click the bottom right-pointing arrow to add it to the list of values to be monitored in the table. The type of output for the data value can be specified by clicking the cell within the **Field Type** column to display a list box of output types (Max, Min, Avg, Sample, or Other). A data field can be deleted from the list of values to be monitored by

right-clicking and choosing Delete. Selecting the **Generate daily values if time range > 1 day** will cause only daily values to be monitored if the time range for the report is greater than two weeks.

Press the **Delete This Report** button to delete this custom X-Y report.

7.2.8 Custom GDD Reports

Custom GDD report are available that are similar to the GDD and GDD2 reports, but allow the user to choose the algorithm used to calculate the GDD.



The **Main Title** and **Sub Title** fields are used to provide headings for the report.

The method used to calculate the GDD is determined by what is selected in **GDD Method**. The **Cutoff Method**, **Temperature Fields, Lower (Base) Temperature, and Upper Temperature Limit** also affect the calculation as explained below as they relate to each **GDD Method**.

- **Simple (single base temperature)** – Compares mean temperature (Tmean) to a **Lower (Base) Temperature** (Tbase). The Tmean value used is based on the **Temp Values to Use** field. If Average Temperature is selected, Tmean equals the **Air Temp Avg Field**. If Min/Max Temperature is chosen, Tmean = (**Air Temp Max Field** – **Air Temp Min Field**)/2. The GDD is calculated as follows:

```
If (Tmean > Tbase) then
    GDD = (Tmean – Tbase) * dataInterval
Else
    GDD = 0
```

- **Upper-Lower** – Uses both the **Upper Temperature Limit** (upperThreshold) and **Lower (Base) Temperature** (lowerThreshold) to calculate the GDD. The method of calculation changes based on both the **Temp Values to Use** field and the **Cutoff Method** field as described below:

  - **Average Temperature**

    - **None** – Not adjusted for upper threshold. Basically the same as the Simple GDD Method.

    - **Horizontal** – If (Tmean > upperThreshold) then
      Tmean = upperThreshold

    - **Intermediate** – If (Tmean > upperThreshold) then
      Tmean = Tmean – (Tmean – upperThreshold) * 2

    - **Vertical** – If (Tmean > upperThreshold)
      then GDD = 0

    The GDD is then calculated as follows:
    If (Tmean > lowerThreshold) then
    GDD = (Tmean – lowerThreshold) * dataInterval
    Else
    GDD = 0

  - **Min/Max Temperature**

    - **None** – Not adjusted for upper threshold. Basically the same as the Simple GDD Method.

    - **Horizontal** – If (Tmax > upperThreshold) then
      Tmax = upperThreshold

    - **Intermediate** – If (Tmax > upperThreshold) then
      Tmax = Tmax – (Tmax – upperThreshold) * 2

    - **Vertical** – If (Tmax > upperThreshold) then
      GDD = 0

    If the above calculation causes Tmax to be below Tmin, then Tmin is set equal to Tmax.

    The mean value is calculated from this new Tmax and Tmin:

    Tmean = (Tmax + Tmin) / 2

    The GDD is then calculated as follows:
    If (Tmean > lowerThreshold) then
    GDD = (Tmean – lowerThreshold) * dataInterval
    Else
    GDD = 0

- **Sine** – This GDD Method is an industry standard also known as the Baskerville-Emin (BE) method. The method of calculation changes based on the **Cutoff Method** field.

- **DoubleSine** - This GDD Method is an industry standard. The method of calculation changes based on the **Cutoff Method** field.

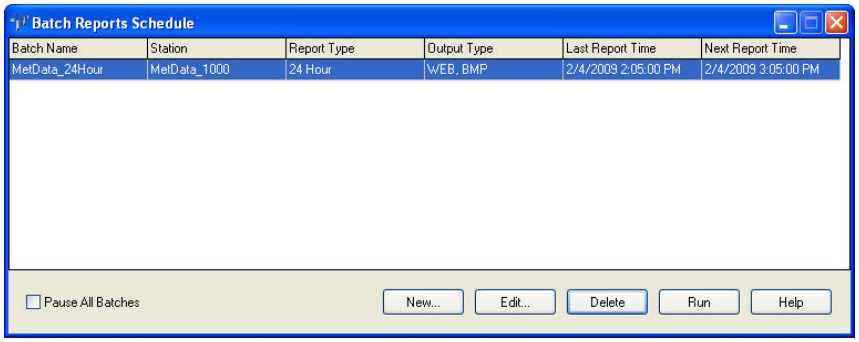
NOTE The **Lower (Base) Temperature** and **Upper Temperature Limit** can be entered in either the **Fahrenheit** or **Celsius** field. When the information is entered into one field, it will automatically be converted to the correct units for the other field.

Press the **Delete This Report** button to delete this custom GDD report.

7.3 Batch Reports

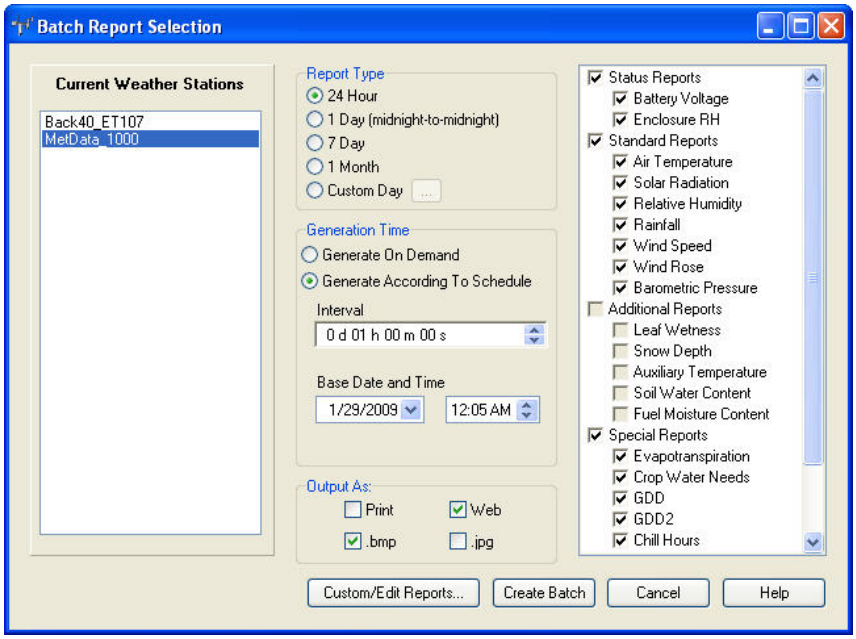
Batch Reports allow you to define reports to be saved and generated at a later time. They can be set up to run on a schedule (automatically) or on demand (manually by the user).

To open the Batch Reports screen choose the Reports | Batch Reports menu item from the menu on the Home screen.



7.3.1 New

To create a new batch report click the **New** button on the Batch Reports Schedule screen. The Batch Report Selection screen is displayed.



This screen is much like the screen shown when manually generating a report except you have additional fields to enter.

Batch reports can be created only for current weather stations (that is, you cannot create Batch Reports for historical data of deleted weather stations).

Select the Output types desired. You can choose any combination of **Print, Web, .bmp, or .jpg**, but you must choose at least one option. (See Section 12 for information on web output.)

Select the Report Type.

24 hour Creates a 24 hour report. The 24 hour period covered starts at the top of the hour and is based on the current PC time.

1 day Creates a 24 hour report (midnight to midnight) for the last 24 hour period.

7 day Creates a 7 day report for the last 7 days, beginning on midnight of the first day and ending at midnight of the last day.

1 month Creates a report for the previous month, beginning on midnight of the first day of the month and ending at midnight on the last day of the month.

Custom Creates a report that starts at midnight and ends at midnight, covering the number of days entered.

Select whether you want to generate on Demand (user initiated creation) or according to Schedule (automatically generated).

When **Generate on Demand** is chosen, a defined report will be run when it is selected from the **Reports | Batch Reports** menu.

When **Generate According to Schedule** is chosen, the report will be run automatically based on the additional fields. The additional fields enabled will be based on the **Report Type** selected as follows:

24 hour Creates a 24 hour report. The report is created based on the **Interval** and **Base Date and Time**. A report will be generated at every **Interval** from the **Base Date and Time**. Each report will cover the 24 hour period preceding the time the report is created.

1 day Creates a 24 hour report (midnight to midnight) for the previous day. The report will be generated daily starting at the **Base Date and Time**.

7 day Creates a 7 day report for the last 7 days, beginning on midnight of the first day and ending at midnight of the last day. The report is created based on the **Interval** and **Base Date and Time**. A report will be generated at every **Interval** from the **Base Date and Time**. Each report will cover the 7 day period preceding the day the report is created.

1 month Creates a report for the previous month, beginning on midnight of the first day of the month and ending at midnight on the last day of the month. The report will be created on the **Day of month to create Report** at **Time to Create Report**.

Custom Creates a report that starts at midnight and ends at midnight, covering the number of days entered. The report is created based on the **Interval** and **Base Date and Time**. A report will be generated at every **Interval** from the **Base Date and Time**. Each report will cover the n day period preceding the day the report is created, where n is the number entered by the user.

Next Select the **Reports** you wish to have generated.

The units used in the reports will be based on the options chosen from VisualWeather's Tools | Options menu item.

After all desired settings have been selected, click the **Create Batch** button. You will then be prompted for a name for the batch report. The batch report name must be unique among all batch reports that have been created.

NOTE As with creating manual reports, the **Report Parameters** screen is shown if special settings for the station have not been entered and need to be (see 7.2 Report Parameters).

7.3.2 Edit

To Edit a batch report that has already been created, select it in the list and click the **Edit** button. The batch report will be loaded in the **Report Selection** screen. Edit the selections and click the **Save Batch** button. The changes will be saved.

7.3.3 Run

All batch reports, including those set up as scheduled, can be run on demand. Select the batch report you wish to run and click the **Run** button. The report will be generated.

NOTE Running a scheduled batch report will not affect its schedule. If you wish to edit the schedule of a batch report, edit the batch report and change its generation time.

7.3.4 Delete

To delete a batch report select it in the list and click the **Delete** button. The batch report will be deleted.

NOTE This action cannot be undone.

8. Station Data

To view a graphical representation of the current weather conditions for all of the stations in your network, select the **Station Data** heading

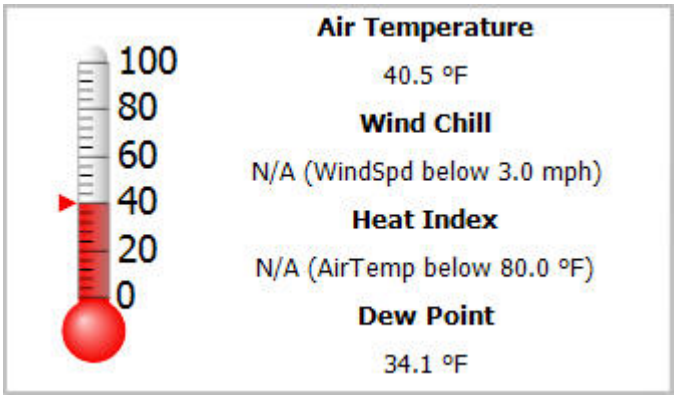
Each station is displayed on its own screen. The tabs at the top of the window can be used to navigate between screens. The data displayed must be collected through scheduled or manual collection. VisualWeather does not actively collect data to be displayed by Station Data.

The data displayed will be based upon the sensors that were selected when the weather station was configured (or, for a custom station, the Data Fields associated with the Real Time Parameters when setting up the Real Time Field Mapping). The units used will be based on the options chosen from VisualWeather's Tools | Options menu item.

NOTE The data is displayed as a project developed with Campbell Scientific's RTMC Pro Development software. The project file is VW_Multistation.rtmc2 and is saved in C:\CampbellSci\VisualWeather\RTMC. If you have RTMC Pro, you may make changes to this project (i.e., display additional components). Once you have made changes to the project, VisualWeather will not modify the project. If you want to revert to VisualWeather's default project, you will need to delete the project file. VisualWeather will then recreate the project the next time Station Data is opened.

The following components are available in Station Data. Listed below each component are the sensors (for pre-configured weather stations) and real time fields (for custom stations) required for each condition to be displayed.

Thermometer



Air Temperature

Sensors: HMP50-ET Temp/RH Sensor, CS500, HMP35C, HMP45C, 107 Temperature Probe, or 108 Temperature Probe

Real Time Fields: Air Temperature

Wind Chill

Sensors: Sensors that measure Air Temperature and Wind Speed

Real Time Fields: (Air Temperature and Wind Speed) or Wind Chill

Note that when using Air Temperature and Wind Speed to calculate the Wind Chill, the Air Temperature and Wind Speed must fall within these boundaries in order for Wind Chill to be calculated:

-50 °F ≤ Air Temperature ≤ 50 °F
3 MPH ≤ Wind Speed ≤ 110 MPH

If either measurement is outside the boundaries, the Wind Chill will be reported as N/A. The condition that caused the Wind Chill not to be calculated will also be specified. See Appendix D for more information on Wind Chill calculation.

Heat Index

Sensors: Sensors that measure Air Temperature and RH

Real Time Fields: (Air Temperature and RH) or Heat Index

Note that when using Air Temperature and RH to calculate the Heat Index, the Air Temperature and RH must fall within these boundaries in order for Heat Index to be calculated:

Air Temperature ≥ 80 °F
RH ≥ 40%

If either measurement is outside the boundary, the Heat Index will be reported as N/A. The condition that caused the Heat Index not to be calculated will also be specified. See Appendix F for more information on Heat Index calculation.

Dew Point

Sensors: Sensors that measure Air Temperature and RH

Real Time Fields: (Air Temperature and RH) or Dew Point

See Appendix C for information on Dew Point calculation.

Compass

Wind Direction

Sensors: 034B, GilSonic, 034A MetOne, 03001 Wind Sentry, 05103 R.M. Young Wind Monitor, or 05350 R.M. Young Wind Monitor

Real Time Fields: Wind Direction

Wind Speed

Sensors: 034B or GilSonic

Real Time Fields: Wind Speed

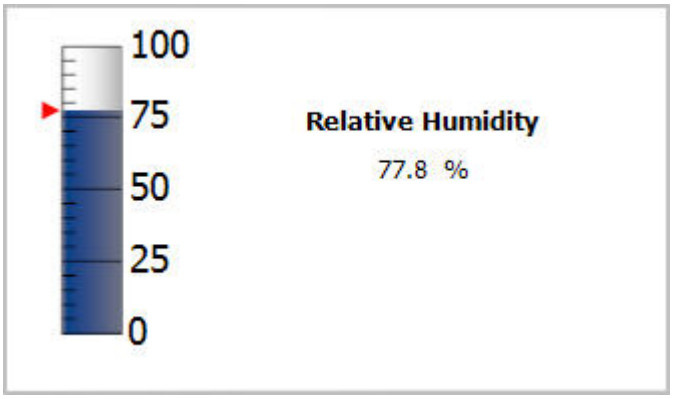
Rain Last 24 Hours

Rain Last 24 Hours

Sensors: TE525-T Tipping Bucket Rain Gage, TE525WS Tipping Bucket Rain Gage, TE525mm Tipping Bucket Rain Gage, or CS700 Tipping Bucket Rain Gage w/syphon

Real Time Fields: Rain Fall

Relative Humidity

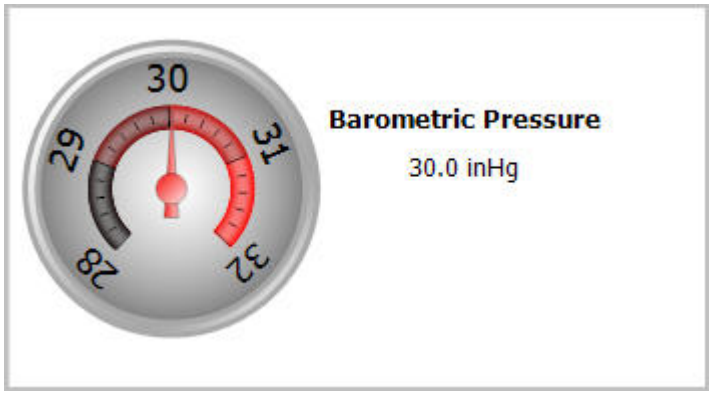


Relative Humidity

Sensors: HMP50-ET Temp/RH Sensor, HMP35C, or HPM45C

Real Time Fields: Relative Humidity

Barometric Pressure

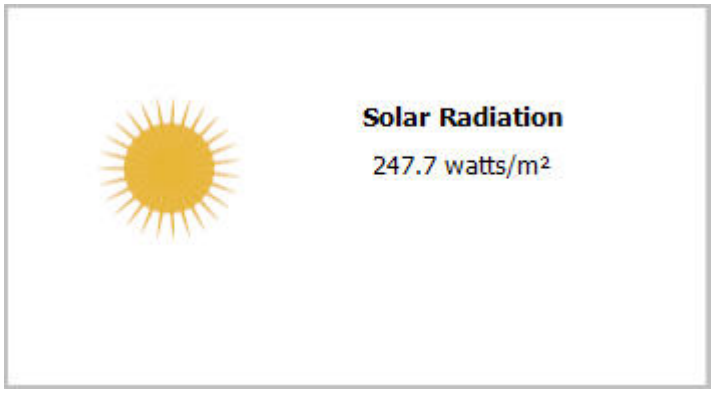


Barometric Pressure

Sensors: CS105MD

Real Time Fields: Barometric Pressure

Solar Radiation

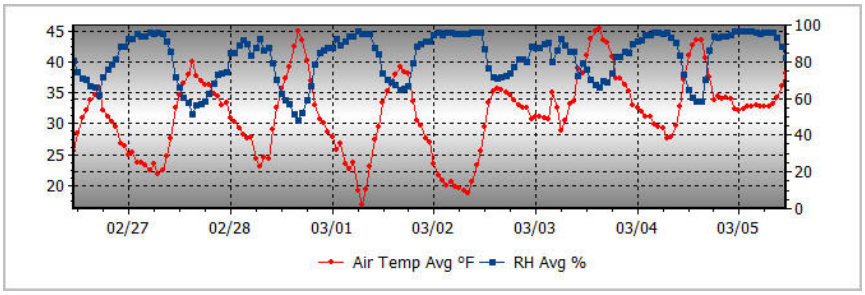


Solar Radiation

Sensors: CS305-ET Solar Radiation or LI200X

Real Time Fields: Solar Radiation

Air Temperature and Relative Humidity

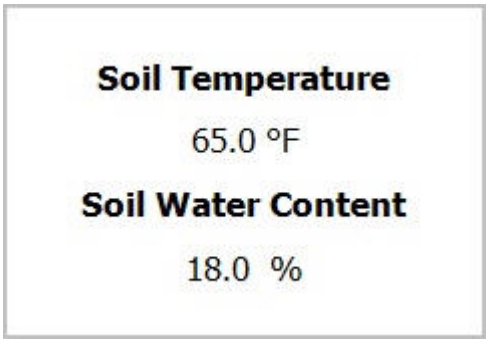


Air Temperature and Relative Humidity

Sensors: Sensors that measure Air Temperature and Relative Humidity

Report Fields: Air Temp Avg and RH Avg (backfills last 7 days)

Soil Temperature and Soil Water Content



Soil Temperature

Sensors: 107 Temperature Probe or 108 Temperature Probe

Real Time Fields: Soil Temperature

Soil Water Content

Sensors: CS615 or CS616

Real Time Fields: Soil Water Content

Battery Voltage

Datalogger Battery Voltage

Real Time Fields: Batt Voltage

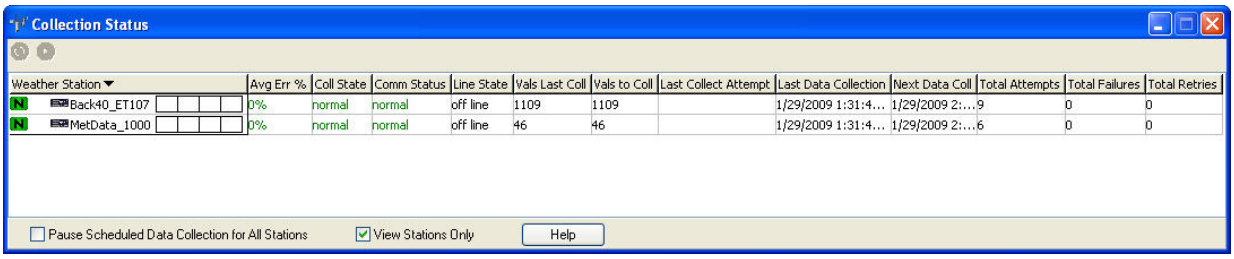
Enclosure RH

Enclosure RH (inside the weather station enclosure)

Real Time Fields: Enclosure RH

9. Monitoring the Data Collection Status

To view the current status of scheduled collection for stations, select the **Collection Status** heading or Network | Collection Status menu item from the main menu of the Home screen.



The Collection Status screen shows the current status of all stations currently configured in VisualWeather. An exclamation icon is shown by all stations with which VisualWeather is currently having trouble communicating. The columns shown are described as follows:

Avg Err % - A running average of the number of communication failures and retries over a period of time.

Coll State - This column provides information on the mode of data collection that the device is in.

Normal - Data is being collected on schedule.

Primary - Data collection will be attempted on the primary retry schedule because of failures of normal data collection.

Secondary - Data collection will be attempted on the secondary retry schedule because of failures of the primary retry schedule.

Schedule Off - The data collection schedule has been toggled off.

Comm Disabled - Communication has been disabled, by the user or by VisualWeather, for the device, a parent device, or the entire network.

Invalid Table Defs - Data collection has been disabled by VisualWeather because the table definitions do not match what VisualWeather expects. Go to the EZSetup Wizard and refresh the table definitions by selecting Update Table Definitions from the Data Files | Mapping screen.

Network Paused - VisualWeather has paused communication in the network.

Unreachable - The device cannot be reached through the network.

Comm Status - A device has four communication states: Normal, Marginal, Critical, or Unknown. The current status of the device will be reflected in this column.

Line State - The state of communication with the device in the network.

Off-line - No communication is taking place with the device.

On-line - Communication for all parent devices for the device has been successful and the parent devices have been put into a transparent state. Therefore, an On-Line state for a device indicates that the communication link is ready for the device, but it may not necessarily be on-line yet.

Transparent - The device is part of an active communication link. For instance, when a datalogger is called using a phone modem, the phone modem will become transparent once communication is established with the datalogger.

Comm Disabled - Communication has been disabled either by the user or by VisualWeather.

Hanging Up - VisualWeather is in the process of shutting down communication with the device.

Vals Last Coll - The number of values that were collected during the last data collection attempt.

Vals to Coll - The number of values that were available for collection during the last data collection.

Last Col Attempt - The date and time that data collection was last attempted with the datalogger.

Last Data Collection - The date and time of the last successful data collection with the datalogger.

Next Data Coll - The date and time of the next scheduled data collection for the device.

Total Attempts - The total number of times VisualWeather has attempted to communicate with the device.

Total Failures - The total number of times the primary and secondary retries for a device have been exhausted before the communication attempt was successful.

Total Retries - The total number of times VisualWeather has attempted to communicate with a device after the original attempt failed.

NOTE Total Retries and Total Failures will equal Total Attempts.

A graph is shown for each station to help show historical communication information about the station. A maximum of 72 bars are shown. Each bar represents 15 minutes. The communication failure percentage determines the height of the bar. It is calculated as: (Failures + Retries) / Attempts. The color of each bar is determined by the following rules:

Green: No Retries, No Failures

Blue: Retries, No Failures

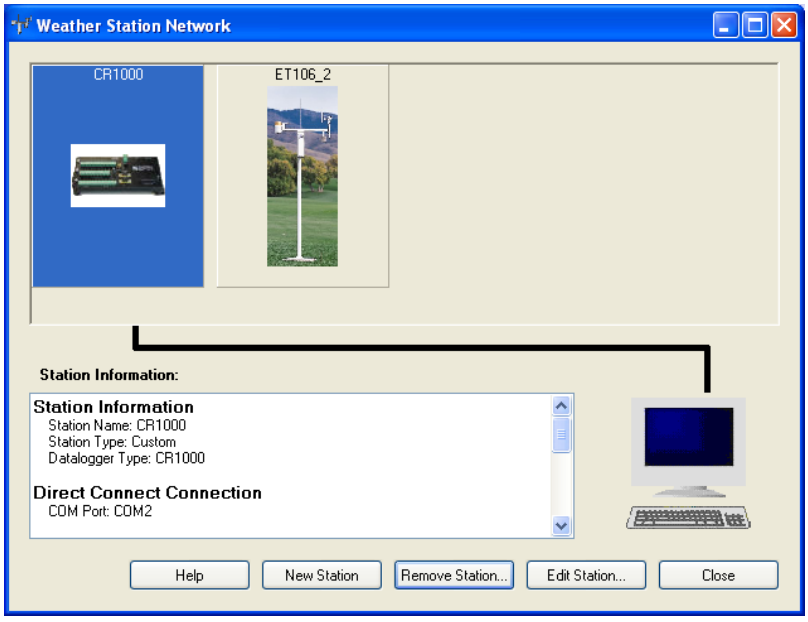
Red: Failures

Gray: No Attempts

Scheduled collection can be paused for all stations in the network by checking the **Pause Scheduled Data Collection for all Stations** checkbox.

10. Weather Station Network

To view all the stations that are currently configured in VisualWeather, select the **Weather Station Network** heading or Network | Weather Station Network menu item from the main menu of the Home screen.



The Weather Station Network screen shows all weather stations currently in the network. Station information is displayed for the station that is currently selected.

To add a new station to the network, click the **New Station** button. The EZSetup Wizard as described in Section 5.1 is opened.

To remove a station from the network, select it and click the **Remove Station** button. The station will become a past weather station. Reports may still be generated for the station with historical data, but no new data can be collected from the station. A station may be removed from the network completely from the Network | Remove Station menu item.

NOTE The Remove action cannot be undone.

To edit the configuration for a weather station, select it and click the **Edit Station** button. The EZSetup Wizard as described in section 5.1 is opened. To quickly move to a specific section of the Wizard, select it from the Progress panel on the left size of the Wizard.

11. Data Mapping

Data mapping is required to associate measurements and final storage data in a custom weather station with the values required for report generation and monitoring of current conditions and status.

11.1 Report Field Mapping

Data mapping required for report generation is done from the Report Field Mapping screen of the EZSetup Wizard. (Report Field Mapping is the second screen under the Data Files/Mapping section of the EZSetup Wizard.)

Each required **Report Parameter** needs to be associated with a value, or **Data Field**, in the datalogger.

To map a value, first select the data table or array ID that contains the value you want to associate from the **Tables** list. When a table or array is selected, the values in that table or array are displayed in the **Fields** list. Click the **Data Field** cell for which you want to map a value, and then highlight a data value from the **Fields** list and click the right-pointing arrow (or double-click the value). The name of the field will be displayed in the Data Field when it has been mapped. To clear an association, right click and select **Clear**. The **Field Units** field should specify the units of the data value from the datalogger. This will be converted as needed for purposes of the reports. If the default unit is incorrect, click within the field to enable a list box from which to select an appropriate unit.

Report parameters required for report generation are shown below. Unless noted otherwise, all listed parameters are required for the specified report. **All parameters used for any one report must have the same interval.**

Battery Voltage

- Battery Voltage Min (required)
- Battery Voltage Max (optional)

Enclosure Relative Humidity

- Enclosure RH Max

Air Temperature (requires one of the following)

- Air Temperature Min
- Air Temperature Max
- Air Temperature Avg

Solar Radiation

- Solar Radiation Avg

Relative Humidity (requires one of the following)

- RH Min
- RH Max
- RH Avg

Rain

- Rain Fall Total

Wind Speed

- Wind Speed Max

Wind Rose

- Wind Speed Avg
- Wind Direction Avg

Barometric Pressure (requires one of the following)

- BP Min
- BP Max

Leaf Wetness

- Leaf Wet AVg
- Minutes Wet
- Leaf Transition Point
- Leaf Wetness Temperature

Snow Depth

- Snow Depth Avg (required)
- Snow Sensor Height (optional)

Auxiliary Temperature (requires one of the following)

- Aux Temperature Min
- Aux Temperature Max
- Aux Temperature Avg

Soil Water

- Soil Water Avg

Fuel Moisture

- Fuel Moisture Avg

Evapotranspiration

- Air Temperature Avg
- RH Avg
- Wind Speed Avg
- Solar Radiation Avg

Crop Water

- Air Temperature Avg
- RH Avg
- Wind Speed Avg
- Solar Radiation Avg

GDD

- Air Temperature Avg

GDD2

- Air Temperature Avg

Chill Hours

- Air Temperature Avg

Dew Point (requires one of the following)

- Dew Point Min
- Dew Point Max

Wind Chill (requires one of the following)

- Wind Chill Min
- Wind Chill Max

Heat Index (requires one of the following)

- Heat Index Min
- Heat Index Max

11.2 Real Time Field Mapping

Data mapping required to monitor Current Conditions and view Station Data is done from the Real Time Field Mapping screen of the EZSetup Wizard. (Real Time Field Mapping is the fourth screen under the Data Files/Mapping section of the EZSetup Wizard.)

The goal is to associate the **RealTime Parameter** with a value, or **Data Field**, in the datalogger. To map a value, first select the data table (typically Public or Inlocs) that contains the value you want to associate from the **Tables** list. When a table is selected, the values in that table are displayed in the **Fields** list. Click the **Data Field** cell for which you want to map a value, and then double-click the value to be mapped in the **Fields** list. The name of the field will be displayed in the Data Field when it has been mapped. To clear an association, right click and select **Clear**. The **Units** field should specify the units of the data value from the datalogger. This will be converted as needed for display purposes. If the default unit is incorrect, click within the field to enable a list box from which to select an appropriate unit.

12. Web Output

Web output can be enabled From VisualWeather's main menu, by selecting Tools | Web Output Options.

When **Web Output Enabled** is selected, the following will occur:

- Station Data launched from the VisualWeather main screen will output images when new data is available. If **Station Data Screens** is selected, each screen will be output as **Local Output Folder**\<station name>.png. If **Individual Station Data Components** is selected, individual data controls will be output as **Local Output Folder**\<station name>.<componentname>.png
- When **Web** is checked in the **Output As** field for a batch report, all reports for the batch will be saved to **Local Output Folder**\<station name>. They are saved as both paginated jpg images and as .html pages
- A webdata.xml file is stored in the **Local Output Folder**. This file contains the list of stations and for each station: the last data values collected and references to batch reports configured to be output to the web. This file is updated when data is collected, and when a batch report is generated.
- Default.htm is located in the web folder. Default.htm uses WebData.xml and constructs a web site that allows the user to see the stations, station data, and batch reports generated for the web.
- When the **Include Station In Web Report Image Paths** option is checked, the image path referenced in each web report is *<station name>/<image name>*. When creating your own website or loading the reports directly into a browser (without using the shipped default.html), you may wish to uncheck this option. With the option unchecked, the web report image path will be just be the image name without the relative path (station name) included. The default for this option is checked.

- If **FTP Enabled** is checked, all files that are being output to the **Local Output Folder** will also be sent to the **Remote Folder** using the specified FTP settings. These files include station data images, WebData.xml, and batch reports.

NOTE In order to set up the web page, the user will initially need to copy default.htm and the <*working directory*>\Web\yui directory to the FTP location. These will not be copied automatically.

Host Address

The FTP server to which the files will be sent.

User ID

The username on the FTP server.

Password

The user's password on the FTP server

SFTP (SSH FTP)

Select the check box to enable SFTP (SSH File Transfer Protocol). Clear the check box to disable SFTP.

Four server types are supported. Three of these are supported by default: FTP (File Transfer Protocol), FTPS (FTP over implicit TLS/SSL), and FTPES (FTP over explicit TLS/SSL). The fourth type, SFTP, is only enabled if this check box is selected.

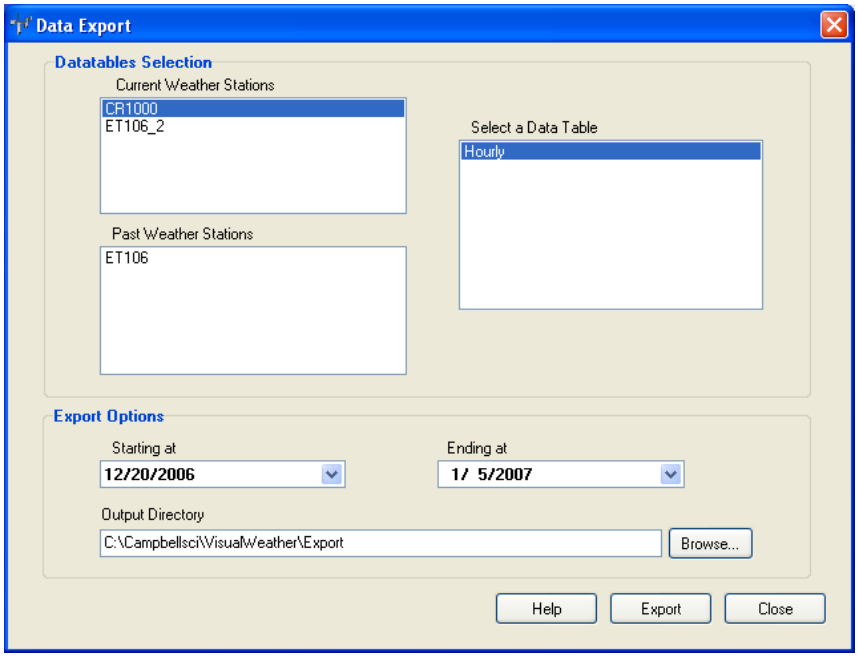
Remote Folder

Selects the folder on the FTP server to which the files will be transferred. The files will be saved to this folder under the FTP server's FTP root directory. Press the button to browse to the desired directory.

13. Exporting and Importing Data

13.1 Exporting Data

Data retrieved from a weather station can be exported to a file for further data processing. From VisualWeather's main menu, select Tools | Export Data.



Highlight the desired weather station name from the list of **Current** or **Past Weather Stations**. The names of the data tables associated with the selected weather station will be displayed.

Select the desired table to be exported in the **Select a Data Table** list. Next select the range of data to be exported using the **Starting at** and **Ending at** fields.

By default, exported data will be saved in the <*working directory*>\Export folder with a name of <*station name*>.dat (the *working directory* is the directory specified in the install and *station name* is the name of the weather station). A different directory can be selected by clicking the **Browse** button.

Click the **Export** button to begin exporting the data.

Data is exported in Campbell Scientific's TOACI1 format (an ASCII comma-separated format with headings). The exported data can be imported into a spreadsheet or other software for further data processing.

13.2 Importing Data

The Import Data function can be used to import data from a data file into VisualWeather's database for a specified weather station. From VisualWeather's main menu, select Tools | Import Data.

Type in the filename to be imported in the **Data File** field or press the browse (…) button to browse to the desired file. If the data file is from an array-based logger, you will also need to specify an associated *.FSL file (file storage label file) in the **FSL File** field and then choose the array to import from the drop-down menu in the **Array** field. (The **FSL File** field and **Array** field will be disabled for data files from table-based loggers.)

To specify where the data should be imported, choose a **Station** and **Table** from the drop-down lists.

VisualWeather will attempt to determine which database field corresponds to each field in the imported data file. This will be displayed in the table on the bottom half of the screen. Changes can be made by clicking on any cell under **DataBase Field** and choosing a different value from the drop-down menu. If no **DataBase Field** is specified, the corresponding **Field from File** will not be imported into the database.

Once all of the required information has been entered, press the **Import** button to begin the process.

14. Backup/Restore Network

The entire weather station network can be backed up to a file. The network can then be restored, if necessary. The backup includes the network, the data for each station, and *.ini files which contain the settings for each station.

NOTE WebData.xml is the only file from the <*working directory*>\Web folder that is part of the backup. Batch reports and/or real time images will need to be backed up by the user if desired.

To create a backup or restore a network, select Network | Backup/Restore Network from VisualWeather's main menu.

By default the backup is saved to C:\Campbellsci\VisualWeather\VisualWeather.bkp. A different folder and/or filename can be specified by pressing the button to display a window from which to choose the folder and filename. After selecting the folder and filename, press the **Backup** button to create the backup file.

To restore a backed-up network, choose the desired **Backup File** and then press the **Restore** button.

NOTE Beginning with VisualWeather 3.0, a restore cannot be performed from a backup file created using a version of VisualWeather prior to version 3.0.

15. Programming Custom Weather Stations

When an ET106, ET107, Toro T107, or MetData1 station is configured in VisualWeather, a program for that weather station is automatically generated based on the sensors chosen during setup.

When custom stations are configured in VisualWeather, you must generate the program yourself if the station has not been previously programmed. Short Cut for Windows (SCWIN) has been included in VisualWeather for this purpose.

SCWIN has a wizard-like interface that steps you through programming a datalogger to measure your sensors and to select the data to be stored in the datalogger's memory. Once a program is completed, SCWIN generates a wiring diagram that aids in connecting your sensors to the datalogger.

SCWIN can be opened from VisualWeather's Tools | ShortCut menu option. Complete information on using SCWIN is included in its on-line help.

16. Advanced Features

16.1 Run On Startup

VisualWeather can be set to open and begin collecting data from the weather stations when your computer is started. From the File menu, select Run On Startup. When a check mark appears to the left of the item, it is enabled. The menu item is a toggle. When the check mark is absent, select the menu item to enable the option. When the check mark is present, select them menu item to disable the option.

16.2 LogTool

VisualWeather includes a LogTool utility that is used to view the communication logs that are generated when communicating with the weather stations. This tool can be opened from Tools | LogTool.

If you are experiencing difficulty connecting with a weather station, a Campbell Scientific applications engineer may ask you to open this utility and provide information from the logs to help troubleshoot the problem. There are four logs, each of which are explained briefly, below.

16.2.1 Log Types

Transaction Log (tran$.log) - This log includes information on the transactions that occur between VisualWeather and devices in the weather station network. Examples of these types of events are clock checks/sets, program downloads, and data collection.

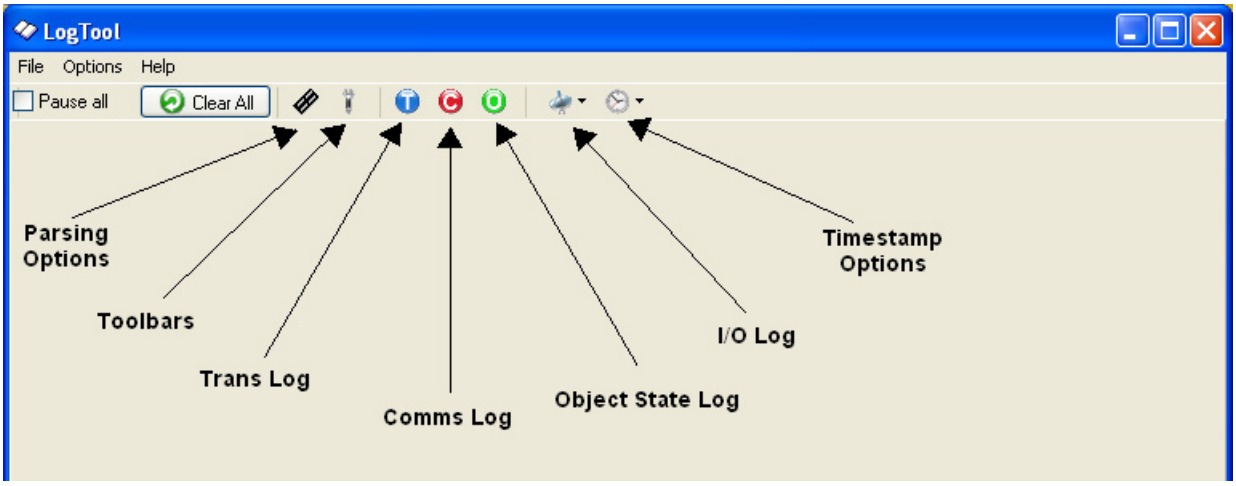
Communication Log (comms$.log) - This log records information on the quality of communications in the weather station network. Three types of messages are recorded: status messages, warning messages, and fault messages.

Object State Log (state$.log) - This log is used for troubleshooting an object in the weather station network. The information in this log conveys the state of an object at a given time.

Low Level I/O Log (io$SerialPort_1) - This log displays low level incoming and outgoing communications for a root device (i.e., serial port).

16.2.2 Using LogTool

When the LogTool is first opened, two logs are displayed: the transaction log and the communication log. The Object State log and the Low Level I/O log can be displayed by toggling their associated button on the toolbar.



Parsing Options - Toggles the display of the message parsing window.

Toolbars - Toggles the display of an individual tool bar for each of the logs. You can pause the display of messages for a tool bar by selecting the Pause check box. You can clear all messages for a log by pressing the Clear Messages button.

Trans Log, Object State Log, Comms Log - Toggles the display of the associated Log.

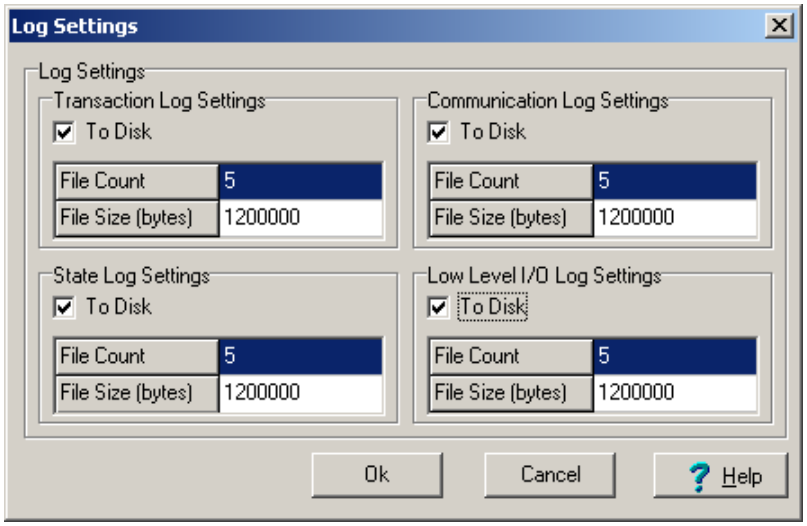
I/O Log - Opens the Low Level I/O log for a specific COM port in a new window.

TimeStamp Options - Allows you to select the format for the time stamp in the logs. If none of the options are enabled (an option is enabled if a check mark appears to the left of the option name), only the time is displayed (hh:mm:ss AM/PM). If Date is selected, a date (MM/DD/YY) will be added to the time stamp. If Military is selected, the time stamp will be displayed in 24 hour format instead of 12 hour format. If ms Resolution is chosen, the time stamp will also include milliseconds.

16.2.3 Saving Logs to File

The log messages currently being displayed on the LogTool screen can be manually saved to a text file by selecting File | Save Log Windows to File. In addition, these logs can be printed by selecting File | Print Log Windows.

Log files can be saved to individual files automatically by selecting Options | Log File Settings from the LogTool menu and selecting To Disk for the appropriate log. In addition to controlling whether the logs are saved to files, Log File Settings also lets you set the size and number of log files that are created. One set of log files each is created for the Transaction, Communication, and Object State logs. For the Low Level I/O logs, one set of logs will be created for each of the root level devices in the network. Once the maximum number of logs have been created (set by the File Count) the next log file created will overwrite the oldest file.



The following settings are used to save the logs to disk as well as to control the number and size of the log files.

To Disk – Selecting this check box enables saving the associated logs to files on the server computer hard disk.

File Count – This setting determines the number of log files to be saved to disk for this type of log. The server will store up to the number specified before overwriting the oldest log.

File Size – This setting determines how big the log file is allowed to grow before being saved to an archived file. The $ sign identifies the active file. Once a file reaches the specified File Size, it is saved to disk with a sequential number beginning with 0 (e.g. tran0.log, tran1.log, tran2.log…).

Appendix A. Evapotranspiration, Vapor Pressure Deficit, and Crop Water Needs

A.1 Evapotranspiration

This appendix explains the process of evapotranspiration (ET) and the methods VisualWeather uses to calculate hourly ET values. It also explains the calculations for vapor pressure deficit of the air and crop irrigation based on ET.

Evapotranspiration is the process of water loss in vapor form from a unit surface of land both directly (evaporation) and from leaf surfaces (transpiration).

The energy required for vaporization comes mainly from the solar radiation and the ambient air temperature. Higher values of solar radiation and ambient air temperature increase ET. As the air near the soil surface saturates with water vapor, the rate of water loss due to evaporation decreases. Therefore, with increasing humidity ET decreases. The wind displaces saturated air with relatively drier air. Thus, at higher wind speeds ET increases. Other factors, such as soil composition, irrigation frequency, rain, and crop type also play important roles that affect the process.

Given the diversity of crops, their heights, ability to absorb solar radiation, foliage resistance to wind, and variability in wind speeds at various altitudes some standards have to be predefined as a basis for comparisons of ET under variable climatic conditions.

For the purpose of standardization the following definition has been adopted[1] for a reference crop surface.

'A hypothetical reference crop with an assumed crop height of 0.12 meters, fixed surface resistance of 70 S/m and an albedo of 0.23'.

This hypothetical reference crop surface closely resembles an adequately watered, extensive surface of green grass of uniform height, completely shading the ground.

The (bulk) surface resistance, rs, consists of resistance to vapor flow through the soil surface and crop leaves. The latter is called stomatal resistance. Stomata are small openings on leaves through which the vapor is lost. For the reference crop the value of rs is fixed at 70 S/m.

Albedo is a crop's ability to reflect the incident radiation. Also known as canopy reflection coefficient, its value for the reference crop is 0.23 (unitless number). Reference crop surface albedo = (radiation energy reflected by reference crop surface) / (solar radiation incident on the reference crop surface) = 0.23.

Over the years the Food and Agriculture Organization of the United Nations (FAO) has published several documents related to evapotranspiration and other agriculture related issues. We allow the option of switching between three ET_o methods:

1. Standardized Reference ET_o for Short Crops (~0.12 meter in height), Grass Reference
2. Standardized Reference ET_o for Tall Crops (~0.50 meter in height), Alfalfa Reference
3. FAO56 Penman-Monteith Method for Estimation of ET_o

The only difference between these methods are the values used for C_n, and C_d in the ET_o equation. These values are described in section 7 below.

The ET_o equation is as follows:

$$ET_o = \frac{0.408\,\Delta\,(R_n - G) + \gamma\,(C_n/(T+273))\,u_2\,(e_s - e_a)}{\Delta + \gamma\,(1 + C_d u_2)} \qquad (1)$$

where, ET_o = reference evapotranspiration (mm/day);
Δ = slope of the vapor pressure versus temperature curve (kPa/°C)
R_n = net radiation at the crop surface (MJ/m²/hour)
G = soil heat flux density (MJ/m²/hour)
γ = psychrometric constant (kPa/°C)
T = air temperature at 2 m height (°C)
u_2 = avg wind speed at 2 m height (m/s)
e_s = saturation vapor pressure (kPa)
e_a = actual vapor pressure (kPa)
$e_s - e_a$ = saturation vapor pressure deficit (kPa)

calculating ET_o:

Because the main climatic factors which determine ET values (solar radiation, temperature, relative humidity, and wind speed) vary throughout the day, VisualWeather uses hourly average data values rather than their daily averages in calculating ET_o

Equations used to calculate the value of each variable in equation (1), related quantities, their units, etc., are presented below.

NOTE Please refer to Table 1 at the end of this Appendix for listings of all quantities and their symbols and units used in the ET_o calculations)

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1. Calculations for Δ[2, 3] (slope of the vapor pressure curve).

$$\Delta = \frac{4098[0.6108\,e^{(17.27T)/(T+237.3)}]}{(T+237.3)^2} \qquad (2)$$

T is temperature in °C.

2. Calculations for R_n (net radiation at the crop surface).

The net radiation, R_n, is the algebraic sum of radiation at the crop's surface, with the sign convention that the incoming radiation is positive and the outgoing radiation is negative. The incoming radiation is higher in energy (i.e., shorter in wavelength) than the outgoing radiation (which is longer in wavelength). The net radiation at the crop's reference surface is:

$$R_n = R_{ns} - R_{nl}$$

where: R_{ns} = Shortwave Radiation = 0.77Rs
R_{nl} = Longwave Radiation

In the daytime incoming net radiation > outgoing net radiation, $R_{ns} > R_{nl}$, therefore R_n is positive.

In the nighttime incoming net radiation < outgoing net radiation, $R_{ns} < R_{nl}$, therefore R_n is negative.

The overall value of R_n is positive over a 24-hour period.

2a. Calculations for R_{nl} (long wave radiation at the crop surface).

The amount of energy radiated back into the atmosphere is proportional to the fourth power of the absolute temperature of a radiating surface (R_{nl} αT^4). This is known as Stefan-Boltzmann's law, in context with black body radiation. The proportionality constant for this relation is known as Stefan-Boltzmann constant, σ.

The value of the Stefan-Boltzmann constant is:

$$\sigma = \frac{4.903 \times 10^{-9}\ \text{MJ m}^{-2}\ \text{K}^{-4}\ \text{day}^{-1} = 4.903 \times 10^{-9} \times 10^{6}}{(1\ \text{day} \times 24\ \text{hours/day} \times 3600\ \text{sec/hour})}$$
$$= 5.675 \times 10^{-8}\ \text{W m}^{-2}\ \text{K}^{-4}$$

However, the radiation emitted into the atmosphere gets absorbed by clouds, vapors, dust and gases like CO_2. Thus the magnitude of R_{nl} would be less than that predicted by the Stefan-Boltzmann law. Therefore, in calculating R_{nl}, the Stefan-Boltzmann law has to be corrected by considering factors such as humidity and clouds and assuming that concentrations of other absorbers remain constant. The following equation is used to calculate the long wave R_{nl}.

$$R_{nl} = \sigma\ T_{hr}^{\ 4}\ (0.34 - 0.14\ (e_a)^{1/2})\ (1.35\ (R_S / R_{SO}) - 0.35) \qquad (3)$$

where, R_{nl} = net outgoing longwave radiation (MJ m^{-2} hour $^{-1}$)
$\sigma = 2.043 \times 10^{-10}$ (MJ m^{-2} K^{-4} hour $^{-1}$)
e_a = actual vapor pressure (kPa)
R_S= measured solar radiation (MJ m^{-2} hour $^{-1}$)
R_{SO} = calculated value of clear-sky solar radiation (MJ m^{-2} $hour^{-1}$)
R_S/R_{SO} = relative value of short wave radiation, $0.2 < R_S/R_{SO} <= 0.8$ (no units)
T_{hr} = hourly average temperature in Kelvin

2b. Calculation of the Radiation Ratio (Rs/Rso)

Rs = measured value of solar radiation (MJ/m^2 /hour)
Rso = clear sky solar radiation; i.e., solar radiation with no cloud cover (MJ/m^2 /hour)

The general equation used to calculate the solar radiation is:

$$Rs = (a_s + b_s\,(n/N))R_a \qquad (4)$$

where
a_s = constant = 0.25
b_s= constant= 0.50
n = actual sunshine hours on a given day
N = expected sunshine hours on a given day
R_a= extraterrestrial radiation

If the day is entirely clear then n = N and
$Rs = (a_s + b_s)R_a = (0.25 + 0.50)Ra$ ˜ $0.75Ra = Rso$.

If the day is entirely cloudy, then n = 0 and $Rs = (a_s)R_a$ ˜ 0.25 Ra.
Therefore the ratio, Rs/Rso on a completely cloudy day would be:
Rs/Rso ˜ 0.25 Ra/0.75 Ra ˜ 0.33 about 0.3.

Therefore, $0.3 < Rs/Rso < 1.0$ define limits of the ratio.

In the nighttime

Rs = 0 at nighttime. However, Rs/Rso should not be taken to be 0 or 0.3, since the sky may be cloud free. For the nighttime the radiation ratio 2 to 3 hours before sunset is used. To identify this radiation ratio 2 to 3 hours before sunset, the following algorithm is used:

When the solar time angle (ω), satisfies the following condition, the radiation ratio is saved and used throughout the night:

$$(\omega_s - 0.79) <= \omega <= (\omega_s - 0.52)$$

where ω_s is the sunset hour angle (in radians). ω_s is calculated as follows:

$$\omega_s = \pi/2 - \arctan[\,\tan(\phi)\tan(\delta) / X^{0.5}] \qquad (5)$$

where $X = 1 - [\,\tan(\phi)]^2[\tan(\delta)]^2$ and X = 0.00001 if X <= 0

2c. Calculations for R_{SO} (clear sky radiation).

Measured values of solar radiation, R_S , are actually extraterrestrial radiation (Ra) reaching the earth corrected by daily conditions; i.e., whether a particular day is clear or overcast. The following equation shows this relation:

$$R_S = (a_S + b_S\,(n/N))\,R_a \qquad (6)$$

Where n = number of hours of actual sunshine (hours)
N =maximum possible number of hours of expected sunshine (hours)

For a completely overcast day n = 0; therefore,

$R_S = a_S Ra$, the constant a_S = fraction of extraterrestrial radiation reaching the earth on a overcast day.

For an entirely clear day n = N

$R_S = (a_S + b_S)Ra$ = clear sky radiation , $a_S + b_S$ = fraction of extraterrestrial radiation reaching the earth on a clear day. Thus,

$$R_S = (a_S + b_S)Ra = R_{SO} \quad (7)$$

When calibrated values of a_S and b_S are not available,

$$R_{SO} = (0.75 + 2 \times 10^{-5} z)Ra \quad (8)$$

Where: z= station elevation in meters

2d. Calculations for R_a (extraterrestrial radiation).

The extraterrestrial radiation, Ra, can be calculated as follows:

$$Ra = \frac{12\,(60)}{\pi} G_{Sc} dr[(\omega 2 - \omega 1)\sin(\phi)\sin(\delta) + \cos(\phi)\cos(\delta)(\sin(\omega 2) - \sin(\omega 1))] \quad (9)$$

G_{Sc} = Solar constant = 0.0820 MJ m^{-2} Min^{-1} =1.36 x 10^3 W/m^2 = 1.36 k W/m^2

$$d_r = \text{inverse relative distance Earth-Sun} = 1 + 0.033 \cos\left(\frac{2\pi}{365} J\right), \text{ J is day of the year} \quad (10)$$

$$\delta = \text{solar declination (radians)} = 0.409 \sin\left(\frac{2\pi}{365} J - 1.39\right) \quad (11)$$

ϕ = latitude of the location (radians) = (π/180) x latitude in degrees

$$\omega_1 = \text{solar time angle at the beginning of period (radians)} = \omega - \pi t_1/24 = \omega - \pi/24 \text{ for hourly step} \quad (12)$$

ω_2 = solar time angle at the end of period (radians) = $\omega + \pi t_1/24 = \omega + \pi/24$ for hourly step, since $t_1 = 1$

$$\omega = \text{solar time angle at midpoint of the period} = \frac{\pi}{12}[(\text{time} + 0.06667(Lz - Lm) + S_c) - 12] \quad (13)$$

time = standard (military) clock time at the midpoint of the period (hours); e.g., t =14.5 hours between 1400 and 1500 hours.

Lz = Longitude of the center of the station's time zone (west of the Greenwich line as 0^o) around the earth in clockwise direction (degrees west of Greenwich)

Lm = Longitude of the measurement site (west of the Greenwich line as 0^o)

S_c = seasonal correction for the solar time (hour) =
$0.1645 \sin(2b) - 0.1255 \cos(b) - 0.025 \sin(b)$ (14)

$b = 2\pi (J-81)/364$ where J is day of the year between 1 (January 1) and 365 or 366 (December 31) (15)

3. Calculation of G (soil heat flux).

The equation to calculate soil heat flux changes depending upon the ET_O method used, and whether it is night or day. The following table describes the equation to use for each method and daytime/nighttime.

Nighttime:

Standardized Short Grass	0.1Rn
Standardized Tall Grass	0.4Rn
FAO56	0.1Rn

Daytime:

Standardized Short Grass	0.5Rn
Standardized Tall Grass	0.5Rn
FAO56	0.2Rn

4. Calculation of γ (psychrometric constant).

$$\gamma = c_P P/\varepsilon\lambda \quad (16)$$

where, c_P = specific heat capacity at constant pressure = 1.013×10^{-3} MJ/kg/°C)
ε = ratio of molecular weight of water to molecular weight of dry air = 0.622
λ = latent heat of vaporization of water = 2.45 MJ/kg
P = atmospheric pressure (kPa)

Substituting values of constants, γ becomes

$$\gamma = 0.000665\ P \quad (17)$$

where the atmospheric pressure is obtained from the following equation:

$$P = 101.3 \left[\frac{293 - 0.0065Z}{293} \right]^{5.26} \quad (18)$$

where, Z = Elevation in meters. In the above calculation the temperature is assumed to be 20°C; hence,

T (Kelvin) = T (°C) + 273 =293. Note that by taking the value of temperature to be 20 °C at all altitudes the temperature dependence of γ has been ignored.

At sea level Z= 0; therefore, P = 101.3 kPa. At a higher altitude the pressure P drops below this value, since the air is less dense. As the altitude increases, P decreases and so does γ.

VisualWeather computes the atmospheric pressure, P, based on the user-entered elevation.

Note that the latent heat of vaporization of water, λ is also a function of temperature. However, its variation with temperature is small enough to be neglected. For the FAO 56 PM equation the value of λ is assumed to be constant, λ = 2.45 MJ/kg.

5. Calculation of $e°(T_{hr})$ (saturation vapor pressure at air temperature T_{hr}).

The saturation vapor pressure is related to air temperature, T

$$e°(T_{hr}) = 0.6108\, e^{(17.27T) / (T + 237.3)} \quad (19)$$

Note that the right-hand side of this equation forms a part of the numerator in equation (3) above.

6. Calculation of e_a (average hourly actual vapor pressure).

$$e_a = e°(T_{hr}) * RH_{hr}/100 \quad (20)$$

RH_{hr} is the average hourly relative humidity (%)

Finally these individual results are combined to calculate hourly values of ET_o by using equation (2).

Denominator = $\Delta + \gamma\,(1 + 0.34\, u_2)$

First term = $0.408\, \Delta\, (Rn\text{-}G) / (\Delta + \gamma\,(1 + 0.34\, u_2))$

Second term = $\gamma\, (37/(T_{hr} + 273))\, u_2\, (e°(T_{hr})\text{-}e_a)) / (\Delta + \gamma\,(1 + 0.34\, u_2))$

ET_o (mm/hour) = First term + Second term

The 24 hourly values of ET_o calculated using equation (2) are added to derive an ET_o (mm/day) value for a day. This process is repeated 7 times for weekly reports and 30 times for a monthly report.

7. Cn, Cd constants

The value of C_n and C_d are dependent upon the ET_o method used and whether it is day or night. The following table shows the values used for each method and time of day.

Method	**Day**	**Night**
ET_O Short	$C_n = 37$, $C_d = 0.24$	$C_n = 37$, $C_d = 0.96$
ET_O Tall	$C_n = 66$, $C_d = 0.25$	$C_n = 66$, $C_d = 1.7$
FAO56	$C_n = 37$, $C_d = 0.34$	$C_n = 37$, $C_d = 0.34$

Additional Notes:

1. VisualWeather accesses hourly average values of temperature (T, °C), relative humidity (RH, fraction), wind speed (u, m/s), and total hourly solar radiation (Rs, W/m2) from the database.

2. Solar radiation values are stored in W/m^2 but these are multiplied by a factor of 0.0036 to convert them into MJ/m^2/hour.

3. Wind speed varies with altitude. Anemometers are either 2 or 3 meters for agronomy, and 10 m above the ground level if the application is in meteorology. The ET_O equation requires that wind speeds be specified at a standard height of 2 meters. The following equation is applied to determine wind speed at 2 m height, regardless of the anemometer position above the ground level.

$$u2 = u^* \frac{(4.87)}{D} \qquad (21)$$

Where, u2= wind speed at standard 2 meter height
D = ln (67.8*Ht -5.42)
Ht= Height is the height of anemometer above the ground level (meters)

If Ht = 2 meters then u2 = u

A.2 Vapor Pressure Deficit of the Air

The vapor pressure deficit (kPa) of the air is the difference between the value of saturated vapor pressure (maximum vapor it can accommodate at a given temperature without condensation) and the actual vapor pressure (the amount of vapor it holds at the time).

This difference is calculated by calculating the saturated vapor pressure of the air

$$\text{VP deficit} = (e°(T_{hr})-e_a))$$

Where,

$e°(T)$ saturated vapor pressure (kPa) of the air at temperature T (Ref. Equation (19) above)

e_a actual vapor pressure (kPa) of the air (Ref. Equation (20) above)

A.3 Crop Water Needs, Crop Coefficients

A crop's life cycle consists of four stages, initial period, development stage, mid-season stage, and the late-season stage.

- The initial stage is the length of time (days) between the planting date and the date at which approximately 10% of the ground surface is covered with green vegetation.
- The development stage is the number of days between the 10% ground cover to nearly full ground cover. The full ground cover often coincides with flowering.
- The mid-season starts at full ground cover and ends when a crop shows signs of maturity, e.g. yellowing of leaves.
- The late season lasts between crop's maturity to its harvest.

During each stage a crop's water need will vary. This requires adjusting the amount of water supply to the crop.

The amount of water (in mm/day or inches per day) needed by a crop is calculated by multiplying the reference crop evaporation (ET_o) described earlier by the crop coefficient (Kc) applicable to that crop in a given stage of its growth.

$$ETc = ET_o \times Kc \qquad (22)$$

These topics, along with useful data applicable to several crops can be obtained by accessing the following web site:

http://www.fao.org/docrep/X0490E/x0490e00.htm#Contents

Information available at this web site should serve only as a guide. *It is the responsibility of users to provide the correct value of Kc applicable to their situation. Contacting local agricultural agencies may provide information about crops grown in that region.*

Table 1. Names, symbols and units of all quantities used in calculations of hourly ET_o values.

		Symbol	Unit
Meteorological Data			
Mean hourly temperature		Ta	^oC
Mean hourly RH		RH	percent
Mean hourly wind speed at 2 meter height		u_2	m/sec
Total hourly solar radiation		Rs	$MJ/m^2/hour$
Data Related to Station's Location			
Elevation		Z	meters
Weather station's longitude Always west of Greenwich line (with Greenwich line as 0 degrees)	*(user-entered)*	Lm	degrees minutes seconds
Weather station's latitude	*(user-entered)*	phi	degrees minutes seconds
North or south of the Equator	*(user-entered)*	N or S	No Units
Standard meridian (midpoint of the time zone)		Lz	degrees
Anemometer position above the ground level	*(user-entered)*	Ht	meters
Data Related to Time			
Day of the year		J or DOY	integer
Begin time hour (military time, hour; e.g., 1400)		tBegin	hour
End time hour (military time, hour; e.g., 1500)		tEnd	hour
Standard (military) time at step's midpoint (e.g.; 14.5)		time	hour
Calculated Values			
Slope of the vapor pressure curve		Δ	$kPa/^oC$
Specific heat capacity at constant pressure		C_p=0.001103	$MJ/kg/^oC$
Ratio of mol weights of water to dry air		ε=0.622	no units

Latent heat of vaporization of water	λ=2.45	MJ/kg
Atmospheric pressure	P	kPa
Psychrometric constant	γ	kPa/^{o}C
Saturation vapor pressure at T	eo(T)	kPa
Actual vapor pressure	ea	kPa
Vapor pressure deficit of the air at T	eo(T)-ea	kPa
Solar constant	GSc= 0.082	MJ/m^2/min
Constant used in seasonal correction	b	radians
	sin (b)	none
	cos(b)	none
	sin(2b)	none
Seasonal correction	Sc	hour
Inverse relative sun-earth distance	dr	meters
Solar declination	δ	radians
Solar time angle at the beginning of period	ω_1	radians
	sin(ω1)	
Solar time angle at the ending of period	ω_2	radians
	sin(ω2)	
Solar time angle at midpoint of period	ω	radians
Length of the step (applies to hourly step only)	t_1 = 1	hour
Extraterrestrial radiation	Ra	MJ/m^2/hour
Clear sky radiation	R_{SO}	MJ/m^2/hour
Ratio of radiation	Rs/R_{SO}	no units
Ratio of radiation with total cloud cover	Rs/R_{SO}= 0.3	no units
Ratio of radiation at nighttime in humid, subhumid climates	Rs/R_{SO}= 0.4 to 0.6	no units
Ratio of radiation at nighttime in arid, semi-arid climates	Rs/R_{SO}= 0.7 to 0.8	no units
Constant used in calculating Ra	a_s= 0.75	
Constant used in calculating Ra, (Z = elevation in meters)	b_s*Z = 2 x 10^{-5}*Z	
Short wave, high energy radiation	R_{ns}	MJ/m^2/hour

Stefan-Boltzmann constant	SIGMA = 2.043×10^{-10}	$MJ/m^2/K^4/hour$
SIGMA*(absolute temp)^4		$MJ/m^2/hour$
Long wave, low energy radiation	R_{nl}	$MJ/m^2/hour$
Net radiation (short wave-long wave radiation)	R_n	$MJ/m^2/hour$
Soil heat flux (if Rs>0 then 0.1*Rn, else 0.5*Rn)	G	$MJ/m^2/hour$
Net radiation - soil heat flux	(Rn-G)	$MJ/m^2/hour$
Denominator (Denom) in the equation for calculating ET_o	Denom = $\Delta + \gamma (1+0.34\ u_2)$	
First term in the equation for calculating ET_o	First term = 0.408 * Δ * (Rn-G) / Denom	
Second term in the equation for calculating ET_o	Second term =(γ * (37/(T+273)) * u2* (eo-ea)) / Denom	
Hourly ET_o value	ET_o (mm/hour) = first term + second term	

REFERENCES

1. Crop Evapotranspiration, Guidelines for Computing Crop Water Requirements, FAO Irrigation and Drainage Paper 56, Richard G. Allen, Luis S. Pereira, Dirk Raes, and Martin Smith, Food and Agriculture Organization of the United Nations, Rome, 1998.

2. 'Uber einige meteorologische Begriffe' , Tetens,O. , Z. GeoPhys., 6:297-309, 1930.

3. 'On the computation of saturation vapor pressure', Murray, F.W., J. Appl. Meteor., 6:203-204, 1967.

Appendix B. Growing Degree Days (GDD)

B.1 Growing Degree Days

This section explains the concept of growing degree-days (GDD) and methods used in VisualWeather to calculate its hourly values.

Growing degree-days (GDD) is a measure of temperature condition that is favorable to plant growth. A range of temperatures is defined by entering lower and upper temperature limits. Temperatures lying within these limits are assumed to be conducive for growth of a given plant. *The lower and upper limits of temperatures favorable to plant growth vary from plant-to-plant and are provided by the user.* Generally, temperatures above 50°F (10°C) are considered favorable for plant growth.

B.1.1 Method

1. An hourly average temperature value, Ta, is compared to the upper and lower temperature limit.

2. If Ta > upper temperature limit, then Ta is set equal to upper temperature limit, and

   If Ta < lower temperature limit, then Ta is set equal to lower temperature limit.

3. If upper temperature limit >Ta > lower temperature limit, then GDD = Ta- lower temperature limit is calculated for every hour.

4. The 24 hourly GDD values are summed.

The GDD value calculated per day is added to the previous day's GDD value. This process is continued and a cumulative GDD value is reported. When the cumulative GDD value reaches a threshold for a given plant value, *as judged by a user*, then it is assumed that it has grown to an extent where it must be trimmed.

Appendix C. Dew Point

C.1 Dew Point

Dew point is the temperature at which air saturates, upon cooling, without change in its water content.

C.1.1 Method

1. The value of saturation vapor pressure, e_s (kPa), is calculated using the polynomial in Ta, the air temperature[1]

   $$e_s=(a0 + Ta*(a1+Ta*(a2+Ta*(a3+Ta*(a4+Ta*(a5+a6*Ta)))))*0.1; \quad (1)$$

   where Ta is the mean hourly temperature and the polynomial coefficients are:

   a0=6.107799961; a1=4.436518521E-1; a2=1.428945805E-2;
   a3=2.650648471E-4; a4=3.031240396E-6; a5=2.034080948E-8;
   a6=6.136820929E-11;

   The quantity e_s is in mbars. Since 1000 mbars = 100 kPA, 1 mbar = 0.1 kPa. Thus, multiplying the polynomial result by 0.1 converts e_s from mbar into kPa.

2. The vapor pressure, e_a (kPa), is calculated from $e_a = RH * e_s/100$, where RH is a measured value of relative humidity (%).

3. The dewpoint, Td (Celsius), is calculated using the equation[2]

   $$T_d = C_3 *\ln(e_a/ C_1) / (C_2-\ln(e_a/ C_1)) \quad (2)$$

   where $C_1 = 0.61078$, $C_2 = 17.558$, and $C_3 = 241.88$

C.2 References

1. 'An Approximating Polynomial for the Computation of Saturation Vapor Pressure', Lowe, P.R., J. Appl. Meteor., Volume 16, Issue 1: 100-103, January 1977.

2. 'Uber einige meteorologische Begriffe', Tetens,O. , Z. GeoPhys., 6:297-309, 1930.

Appendix D. Wind Chill

D.1 Wind Chill

Wind chill is a degree of 'coldness' experienced by exposed human skin due to increasing wind speeds at a given ambient temperature. Wind chill temperature drops with increasing wind speeds at a constant air temperature or with decreasing air temperatures at a constant wind speed. The wind chill effect is more pronounced when the wind speed increases and air temperature drops. Since the degree of coldness varies from person-to-person, the wind chill may have different meaning to different individuals in the same environment.

Wind chill temperatures are meaningful at wind speeds between 3 mph and 110 mph and temperatures between -50°F and 50°F. If either measurement is outside of these boundaries, the wind chill will be reported as N/A.

D.1.1 Method

The wind chill equivalent temperature (°F) can be obtained by using the following equation[1]:

$$\text{Wind Chill (°F)} = 35.74 + 0.6215T - 35.75\,(V^{0.16}) + 0.4275T\,(V^{0.16})$$

where, T = Air Temperature in °F and V = Wind Speed in mph.

VisualWeather calculates wind chill from the raw data of average values of temperatures and wind speeds. Users need not enter any parameters to calculate the wind chill.

D.2 References

1. Bulletin of the American Meteorological Society, pp. 1743-1744, Vol. 74, No. 9, September 1993.

2. National Weather Service Announcement, August 2001, http://205.156.54.206/er/iln/tables.htm.

Appendix E. Chill Hours

E.1 Chill Hours

Chill hours represent the number of hours the temperature stayed at or below a certain base (or reference) temperature provided by the user.

E.1.1 Method

1. The hourly average temperature value, Ta, is compared to the base temperature.

2. If Ta < = BaseTemp, then the number of chill hours = 1, and
   If Ta > BaseTemp, then the number of chill hours = 0

3. A value of either 1 (if the hourly average temperature stayed at or below the base temperature) or 0 (if the hourly average temperature stayed above the base temperature) is assigned to each hour of the day.

4. These values are summed at the end of each 24-hour period. The total value represents the number of chill hours; i.e., the number of hours the temperature remained at or below the base temperature.

Appendix F. Heat Index

F.1 Heat Index

Heat index is the perceived temperature as influenced by relative humidity. For example, an air temperature of 90°F would feel like 132°F if the RH was 100%.

The equation is only useful if air temperature > 80°F (27°C) and relative humidity > 40%. VisualWeather will report the wind chill as N/A if air temperature is < 80°F (27°C) or relative humidity < 40%.

F.1.1 Method

Heat index equivalent temperature (°F) can be obtained by using the following equation[1].

$$HI = -42.379 + 2.04901523T + 10.14333127R - 0.22475541TR - 6.83783x10^{-3}T^2 - 5.481717x10^{-2}R^2 + 1.22874x10^{-3}T^2R + 8.5282x10^{-4}TR^2 - 1.99x10^{-6}T^2R^2$$

where, HI = heat index in °F, T = air temperature in °F, and R = relative humidity in percent (e.g., 30).

VisualWeather calculates heat index from raw data of average values of temperature and relative humidity. Users need not enter any parameters to calculate heat index.

F.2 References

1. The equation used in this calculation is from the National Weather Service; a good explanation may be found at http://www.srh.noaa.gov/bmx/tables/hindex.html

2. Campbell Scientific also has a "Heat Index" Application Note at ftp://ftp.campbellsci.com/pub/outgoing/apnotes/heatindx.pdf

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